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DYNAMIC SKIAMETRY

ITS THEORY AND PRACTICE

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and

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PREFACE

The growing recognition of the importance and value of dynamic skiametry as a method of ocular refraction, together with the conspicuous lack of anything like a clear working textbook on the subject, has created a demand among refractionists which can no longer be ignored or denied.

To meet this demand, the authors have prepared this book. The original premises and the subsequent developments of dynamic skiametry have been carefully gone over, the essential and useful sifted from the controversial and sheerly academic, and the whole reduced to a practical, working system of applied refraction, for the use of the practitioner in determining and correcting the visual errors of his patients.

The first part of the book is devoted to a brief and not too technical consideration of the optical and physiological factors involved; the second part contains a description of the general and special technic of the procedure; and in the third part will be found explicit, step-by-step directions for the performance of the test in its various applications. By following this logical, sequential order of presentation, it is hoped that the reader will be enabled, with the help of the book, to carry out the procedure intelligently and successfully.

During the preparation of the manuscript it was suggested to one of us that a chapter be included on "What dynamic skiametry will *not* do." The suggestion was not carried out, but it contains an admonition well worth

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stressing. Dynamic skiametry will not do miracles, nor does it furnish a solution to all the problems and difficulties of ocular refraction. But, as its inventor, A. Jay Cross, was wont to say when this was pointed out to him, "It is a splendid *finder*." It discloses refractive conditions and uncovers clews in a way that no other method of examination does. And it affords the only objective means of measuring, with any approximation of accuracy, refractive errors as manifested at near distances or with the ocular muscles in action.

It cannot be too insistently repeated that the findings of dynamic skiametry, by whatever technic practised, apart from other tests, are not conclusive. To estimate the error and its correction from them alone is as irrational as to attempt to determine the cubic area of a structure by measuring only one dimension. This test gives only relative data, whose value lies in their correlation with other findings. On the other hand, it gives data of the highest order of importance, which can be obtained by no other means.

One word more. This book is a textbook on dynamic skiametry. It has been frequently necessary, of course, in discussing the subject, to refer to the application and significance of other tests and their results. In all such instances it has been assumed that the reader is familiar with the technic and interpretation of the other procedures referred to.

THE AUTHORS.

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CHAPTER I

OPTICAL PRINCIPLES OF SKIAMETRY*

The true explanation of the shadow phenomena and other occurrences in skiametry, on the basis of physical optics, has been a subject of discussion ever since skiametry came into use as an objective method of ocular refraction. Fortunately for the practice of refraction, it was not essential that these phenomena be optically accounted for in order that the method should be clinically applied. The phenomena themselves, and the recognition that they behaved thus and so under certain stipu-

*The terms "retinoscope" and "retinoscopy" are misnomas, inasmuch as with this instrument and by this method of refraction we do not view the retina, far less examine it, but base our findings on the observation of movements of the light reflex at the pupillary plane, and the apparent movements of the shadows which follow the light movements. They have therefore been discarded from the terminology of modern oculo-refractive science, and replaced by the words "skiascope" and "skiametry." Even these are not quite accurate, since it is not the shadows but the light reflex whose movements we observe. But they are considerably nearer accuracy than the older terms. Throughout this book, therefore, the modern terms will be employed:

SKIAMETRY *for* RETINOSCOPY.
SKIASCOPE *for* RETINOSCOPE.

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lated conditions, were sufficient, in general, for all practical purposes of the objective test. We could, in short, for the time being thankfully accept and avail ourselves of these, without understanding the precise optical happenings involved in their production. But, of course, everyone has realized throughout that a correct and intelligent understanding of the underlying principles of physical optics was an indispensable condition to the maximum development of the test, and especially to the highest development of the optical agencies for carrying it out.

The original idea that the fundus of the eye acted as a reflector to the light thrown into the pupil by the skiascopic mirror, and that the subsequent phenomena were therefore to be explained on the basis of a single reflection system, starting at the source of illumination and ending at the observer's retina,—if, indeed, such an idea was ever entertained by optical physicists,—did not long hold its place. It was not a very difficult matter to show that the light which reached the patient's retina lost its undulatory and dioptric identity there; that it was diffused by the retinal elements, and that the illuminated fundus itself became a secondary source of illumination, from which the light-waves started, *de novo,* as points, on their divergent path outward.

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From the practical standpoint, this recognition greatly simplified the problem. Whatever might be the physical explanation of the shadow phenomena, at least it was clear that the emergent light waves with which the refractionist had to deal in his objective test were to all intents and purposes original emanations, upon which were impressed only those dioptric qualities which the dioptric conditions of the eye itself gave to them. To the extent that the dioptric qualities of the emergent waves could be objectively and accurately determined, they represented the dioptric conditions of the eye.

But it did not by any means solve or settle the physico-optical aspects of the problem, but, if anything only further complicated them. Indeed, to those who viewed the matter superficially, it was positively misleading. From a mistaken conception of the rolè played by the light before it entered the patient's eye, they jumped to the equally mistaken conclusion that this played no part at all in the resultant phenomena. But thoughtful men recognized that there were still elements in the system which were not explicable by the behavior of the emergent waves.

It is only comparatively recently that the matter has been given intelligent analysis, and the fact pointed out that we have to reckon with two separate and distinct optical systems,

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—the illumination system and the observation system—each of which has its own part and value in the production of the various phenomena. For the working out of this analysis, or at all events for its reduction to concrete terms, credit is chiefly due to Professor James P. C. Southall, of the Department of Physics of Columbia University.

We shall not undertake here to present Professor Southall's analysis of the matter in anything like its fullness. That would entail a degree of mathematical demonstration which would be out of place in a work of this character. We shall content ourselves with giving a brief, descriptive, and as far as possible non-mathematical, account of the optical theory involved.

We shall, however, with permission, avail ourselves of some of the excellent diagrams used by Professor Southall, which we understand were drawn for him by his associate, Mr. C. L. Treleaven. And if we vary from the author's description, it is not that we have any idea that we can improve on it, but rather because we must be at once a little briefer and a little less technical.

In Fig. 1, the luminous source S is assumed to be a single point of light. The circle of light at the pupil is represented by a circle described about A, the pupillary center, with a diameter

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AD, AE, which, of course, constitutes the section of a cone of light, with S as its apex. (It is not exactly a circle, but for convenience sake may be so regarded.) If this cone he projected to cut the retinal plane at E′ D′, the circle of

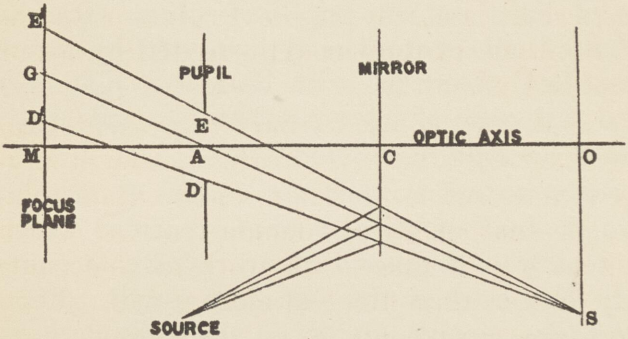

Fig. 1. Diagram of the illumination system in skiametry. From Prof. James P. C. Southall's article on "The Optical Principles of Skiascopy" in the Journal of the American of the Optical Society of America and Review of Scientific Instruments, Vol. xiii, No. 3, September 1926, to whom acknowledgment is due for permission to reproduce.

light on the retina is represented by a circle drawn about a center G, with a diameter GD′, GE′. This, strictly speaking, ends the illuminating system; for here the circle of illumination becomes, as previously stated, a secondary source of light, from which the light waves start *de novo*, on their outward journey, without regard to the incident angle at which they reached the retinal plane.

We now come to the observation system,

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which, however, as will appear, is still part and parcel of the illumination system, regarded from a different angle. The observer's eye is situated at C, the central peephole of the mirror. The central projection of the retinal circle of light on the pupillary plane from this point of observation is represented by a circle described about K, with diameter KD′, KE′. And this cone of light constitutes what may be called the field of observation.

But the fact is that the source of illumination, instead of being a single point of light, is in reality a luminous circle, usually considerably larger than the patient's pupil. Fig. 2, therefore, represents S as the center of this luminous circle, with diameter S^1, S^2, and the region of radiation at the pupil by projection lines drawn from the extreme limits of the luminous source, S^1 and S^2, to the extreme limits of the pupillary area, E and D. Projected still further, to the retinal plane, the illuminated area is represented by a circle described about G, with diameter GF, GH. So much for the strictly illumination system.

Regarding this now, from the standpoint of the point C, where the observer's eye is situated, the projection of the pupillary circle of illumination from this point will be represented by a circle described about K, with diameter KJ, KL, (indicated by dotted lines). On the

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retina, this observation circle, projected as a cone from C, the peephole, will be represented by a circle described about G, with diameter GF, GH. It is, however, the pupillary circle

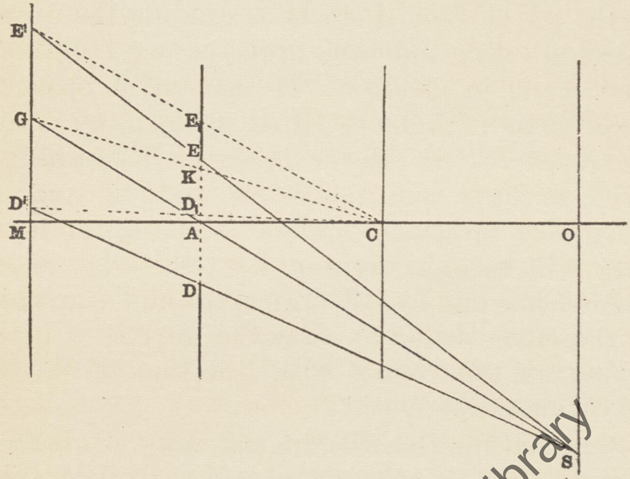

Fig. 2. Diagram of the illumination and observation systems in skiametry. From Professor James P. C. Southall's article on "The Optical Principles of Skiametry" in the Journal of the Optical Society of America and Review of Scientific Instruments, Vol. xiii, No. 3, September 1926, to whom acknowledgment is due for permission to reproduce.

of light which constitutes the field of observation.

Only that portion of the pupil, therefore, which is included in the cone CJL will appear to the observer to be illumined; and that, of course, will depend upon the tilt of the mirror, which is the plane of the source of illumination.

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In Fig. 2 it will be seen that this observational circle of light at its upper boundary overlaps the surface of the eye outside the pupils, from E to J, while at the lower boundary, a margin of the pupil, from L to D, is outside the observational cone, and thus appears to be unillumined, i. e., in shadow. If the entire observational cone of light be tilted upward, by tilting the plane of the mirror upward, the pupillary circle of light will also move upward, and the margin of apparent shadow at the lower boundary will become greater; i. e., the edge of the shaded margin L will appear to move upward, in the same direction that the mirror is tilted, giving an apparent "with" motion of the observational shadow.

So much for the illumination and observation systems, which take no account of the ocular media through which the light is passing, assuming that they are non-existent. In addition, we have a dioptric system, which exercises no influence upon the geometric paths and relationships of the light as determined in the two systems described, but impresses certain focal or dioptric values on the light-waves as they pass through the media of the eye. What these dioptric values are which are impressed upon the *entering* light, important as it is to the subjective aspects of vision, does not concern us at all in our objective test, since the entering

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waves are all diffused at the retina, and start outward again as new emanations from point-sources. It is the dioptric values given by the media to the *emergent* light which we have to identify and measure.

To go back to our diagrams, MAC represents the optical axis, with the focus point M at the retinal plane. Quoting Southall verbatim for a moment, "An optical image of the illuminated area of the fundus will be formed in this plane, which will be real and inverted, or virtual and erect, depending on the position of the focus point. Thus, if the distance of the center A of the pupil from the focus point is denoted by u, that is, if $u = MA$, then (on the supposition that the positive direction along the axis is the direction in which the patient is looking) a positive value of u will mean that the image in the focus plane is virtual, whereas a negative value of u will generally mean that the image is real. The focussing, or state of refraction, may be measured by the reciprocal of the abscissa u, i. e., by the magnitude U 1/u, where the value of U will be expressed in dioptries, provided u is measured in meters."

In short, the purpose of the skiascopic test is to find the value of U by measuring u, i. e., by locating the focussing point. Quoting Southall again, "The nearer the focus plane is to the mirror, i. e., the shorter the interval between

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the focus point M and the center C of the peephole, the larger will be the size of the 'reflex circle,' and in the limiting case when the points M and C are actually coincident, the diameter of this circle will be infinite. This particular condition, when the patient's eye is focussed on the mirror, can be determined, theoretically at least, with very great precision, because then the reflex should appear to be absolutely stationary, (although in reality its speed will be infinite), as the mirror is tilted one way or the other in the given meridian. This special position of the focus point M is called the neutral point, or point of reversal of the movement of the reflex; and as skiascopy is usually practiced, the method consists in so adjusting the optical system that there is no movement of the 'shadow.' "

In the actual practice of the test we do not, as a rule, locate with our mirror the position of the focussing point. By means of the interposition of a lens of known strength we force a focus point, and then subtract the lens from the dioptric equivalent at which the focussing is forced.

"While the whole purpose of the method of skiascopy is to determine the value of U," Professor Southall admonishes, "and therefore to find the position of the focus plane, it is perhaps important to emphasize the fact that the

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observer does not actually ever see the optical image of the fundus. On the contrary, his whole attention is concentrated on the apparent movement of the reflex in the pupillary plane, which enables him to infer where the focus plane must be, and thence to determine the state of refraction of the optical system."

All of the foregoing considerations are based on the assumption that a plane mirror is used as a source of illumination. If a concave mirror be employed, of sufficiently small radius of curvature that its focal length is less than the distance between the observer and the observed eye, then the whole illumination and observation system is reversed, and the movements of the observation field will be in the opposite direction to that described in connection with the plane mirror. This is due to the fact that the effective source of illumination is a real image of the original light-source, made between the mirror and the patient's pupil, and this real image moves in the same direction as the mirror.

The accompanying diagram and its description, taken from Lionel Laurance's "Visual Optics and Sight Testing," demonstrates the action of a concave mirror in retinoscopy in a case of hyperopia:

"S is the source of light, M the mirror, and O the observed eye. Light diverges from S to the

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mirror and is converged to the real conjugate image S′, from which the light again diverges to illuminate the fundus at F. The rays diffused by the fundus emerge into the air as if divergent from the virtual far point R. If the mirror be rotated to M′, to the left, S′ also

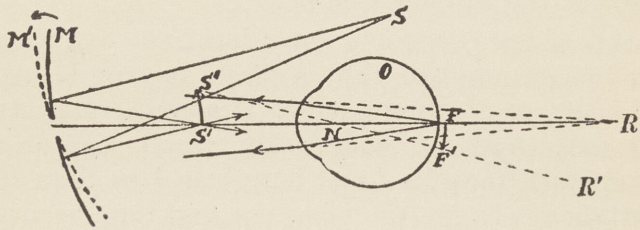

Fig. 3. Diagram of effect of concave mirror on illumination system in skiametry. From "Visual Optics and Sight Testing," by Lionel Laurance, to whom acknowledgment is due for permission to reproduce.

moves to the left toward S″, F moves to the right to F′, and R also to the right to R′. Now, R and R′ being virtual, the observer behind M sees the reflex as moving toward the right, or in an opposite direction to that of the concave mirror M. Similarly it can be shown that for any other refractive condition the reflex movements are reversed to those of the plane mirror on account of S′ being real instead of virtual."

This, however, has no dioptric effect upon the emergent light waves, which, as before explained, are *de novo* emanations from the retinal point-source. Its effect is sheerly on the

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illumination and observations systems. But it does, of course, have the effect of making the apparent movements of the reflex, under the various dioptric conditions of the eye, just the opposite of what they would be with a plane mirror, for the obvious reason that the whole field of observation is reversed to begin with.

It used to be a rather common practice to use concave mirrors for skiametry, because of the greater intensity of illumination obtainable by their means. Since the introduction of the self-illuminating skiascope, with its brilliant lighting, and the reduction of the distance which the light has to travel, this necessity no longer prevails. In any case, for reasons presently to be explained, concave mirrors cannot conveniently be used for dynamic skiametry.

This analysis of the optical principles of skiascopy gives rise to some interesting considerations concerning the means of producing and controlling the illumination and the observation fields in the interests of efficient skiametry.

Since we now know that there is nothing mysterious or significant about the so-called "shadows," but that the optical phenomenon consists in the movement of the reflex circle of light; and in view of the fact, so pertinently stressed by Professor Southall, that the observer does not actually see the optical image

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of the retina, but concentrates his attention on the movements of the reflex at the pupillary plane; it is evident that the smaller this reflex can be made, the better it is for observational purposes, because the more readily it can be made to overpass the pupillary margin, and therefore the easier to watch its movements. The ideal illumination from this standpoint would be sheer point-illumination. But this, of course, would be impracticable from the standpoint of light intensity.

Again, since the optical reflex reaches the pupillary plane through the media of the eye, including the cornea, it is subject to all the spherical aberration pertaining to those media; and these aberrations are worst at the periphery of the pupil. This furnishes another reason for the advantage (apart from intensity) of a small reflex circle. In this respect, again, the ideal illumination would be point illumination.

Finally, the illumination and observation systems themselves, as produced in actual practice, are not the simple, axial or plane affairs that they are represented, for convenience sake, in our diagrams. The light is not thrown into the eye along the optical axis; and the illuminated areas are not true planes, but curved surfaces, for which only a mean plane can be postulated. The actual geometric relations of the systems

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are therefore quite complicated; and the greater the number of point-sources of illumination, i. e., the more circles overlapping each other in the observation field, the greater the complication,—which, as explained, is still further complicated by the spherical aberration of the ocular media.

All of these considerations argue for the ideal utility of a single point source of illumination, if it were practicable from other standpoints; which, unfortunately, it is not. But, in default of that, they still argue for coming as near to a point-source as is consistent with adequate intensity, and other practical requirements. Undoubtedly, this is the real advantage gained from the use of the concave mirror, which, in the process of reversing the field, also makes it smaller. But, as previously stated, there are practical objections to the concave mirror, especially in dynamic skiametry.

Another practical consideration which emerges from our analysis of the optical theory of skiascopy is that "with" movements of the reflex are more readily observed, and their point of neutrality more nicely determined, than "against" movements. The reasons may be briefly stated. When the reflex appears to be moving in the same direction with the tilt of the mirror, it is clearly a motion of the reflex itself, viewed at the pupillary plane, on which

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the observer's eye is fixed. When, on the other hand, the reflex appears to be moving in the opposite direction to the tilt of the mirror, it is plain that the motion is not that of the reflex itself, but of an aerial image of the reflex somewhere between the patient's pupil and the observer's eye. But the observer's gaze still is, and must be, concentrated on the pupillary reflex; so that in case of "against" movements he is obliged to fix and concentrate at one point, while noting movements at another. So marked is the effect of this discrepancy that when neutralization is approached it is almost impossible to perceive movement at all. Quite commonly, when watching "against" movements, they seem to go into neutralization and stay therefore quite an appreciable interval of lens power before reversal becomes apparent.

Streak Skiascopy

Within the past year or two a new principle of technic in skiascopy has been introduced, known as streak skiascopy, which admirably meets the demand for an approximation of point-light source of illumination combined with adequate intensity. The streak skiascope substitutes for the circle of light a rectangular bar of light, produced by the shape and form of the filament and reflected by the plane mirror, which, to all intents and purposes, may be regarded as a row of light-points. It does not

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overlap the pupil, along its edges, and its movements across the pupil, when moved at right angles to itself, can therefore be observed with great ease and accuracy, especially as its brilliancy draws a sharp contrast between the illumined and unillumined portions of the pupil, giving a highly refined manifestation of the reflex. Being practically point-illumination, its limits are clearly defined, and because of its form it is negligibly affected by the spherical aberration of the eye media. In any case, also because of its form, its motion can easily be watched in the central portion of the pupil, where such aberration is itself negligible.

There is, moreover, another feature about the streak skiascope which adds greatly to its working value. The straight line of light which it produces can be changed in width and intensity, and rotated through all the meridians of a circle, rendering the observation of lateral aberrations, i. e., astigmias, and their axes, exceedingly easy and accurate, even in low degrees of error, and in the small pupils which so commonly attend dynamic skiametry.

All of these features serve to make streak skiascopy an invaluable application of the optical principles of skiascopy to the performance of dynamic skiametry, meeting the very difficulties which constitute the peculiar stum-

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bling blocks of this test so far as its objective aspects are concerned.

It would be idle to pretend, of course, that streak skiascopy affords all of these advantages without a corresponding tax upon the care and skill of the operator. An instrument of this character is not, and cannot be, a penny-in-the-slot automaton, delivering ready-made data, or relieving the operator of all work and responsibility. It is an aid to his own skill. And it is inevitable that the more refined the results to be obtained, the greater the degree of skill and care demanded in the use and interpretation of the instrument. However, as that is the price of *all* progress, in every applied science, it can hardly be charged against the streak skiascope, but should rather be credited in its favor. There is none of its demands that cannot be readily met with ordinary application and practice; and the results amply repay the effort.

One of the features which may be regarded as a tax on its virtue, arises out of the extreme refinement of the reflex manifestation. It is so highly refined that the shadow values differ noticeably at different levels of the pupillary area,—a phenomenon likely to confuse the unwary operator. But this, of course, is easily avoided by proper care as to the axial line along which the observation is made; and the small

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pupil which is usually presented in dynamic examination also minimizes the likelihood of confusion. The fact is, the streak instrument gives a field of observation quite *different* from that to which the user of an ordinary skiascope is accustomed, and to this he must accustom himself. When he has done so, however, by a little study and practice, he will find that the "difference" in the field is all in the nature of a marked superiority, yielding observational data and accuracy that are unattainable with the ordinary instrument.

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CHAPTER II

GENERAL CONSIDERATIONS

Dynamic skiametry is a method of examination, devised by the late Andrew J. Cross, of New York City, some thirty-eight years ago, for measuring the refraction of the eye by means of the shadow-neutralization test with the ciliary muscle in contraction, i. e., with some of the accommodation in force.

Cross based his working theory on two physiological principles:

1. That a muscle in action and heavily burdened will accept assistance more readily than a muscle at rest or when carrying only a normal load.

2. That accommodation and convergence are normally related in a more or less fixed ratio, and that when accommodation is adjusted, by lens assistance, to the convergence in that ratio for any given distance, the eye will maintain that ratio rather than surrender any of its accommodation.

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To quote Cross himself: "The principle involved is a very simple one. It is well known that a pound weight placed on the shoulder of a sturdy man creates no appreciable burden or discomfort. But load this same man down almost to the limit of his endurance, and then add this pound of additional weight, and its presence will be felt immediately. So in dynamic skiametry a call is made for a pronounced increase in the tension of the accommodation by having the patient read a series of letters placed either on the operator's brow, attached to his skiameter,* or to a fixation stand, then, by varying this tension as the judgment may teach, and by being able easily to supply required artificial lens power, the accommodation is reduced to its normal relationship with convergence. And most eyes, no matter what the age of the patient, will only surrender the accommodative *excess* which has been required to sustain near vision."

The contraction of the ciliary (accommodation) and that of the internal recti (convergence) are forced into action by having the patient "fixate" some near point. By so doing, the patient brings his two visual axes to the point fixed, i. e., he converges perfectly; but he may or may not accommodate sufficiently for

*It was only in the very early beginnings of his work that Cross used series of letters on his targets. He soon replaced them, at Professor Woll's instigation, with irregular groups of dots, as being more effectual in fixing attentive accommodation.

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the distance of the fixation target. Supposing that he does so accommodate, and focuses the target accurately, the reflex, being examined at this point, will of course be neutral, moving neither with nor against the mirror, since the emergent waves are focussed there.

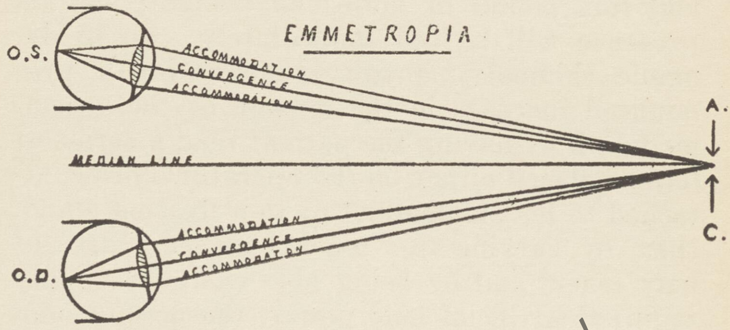

Fig. 4. Showing relationship between accommodation and convergence in emmetropia. (From Cross.)

If the patient is normal, the ratio between his accommodation and convergence at this point is the normal, comfortable ratio, and the placing before his eye of plus lens power will not tempt him to disturb that relation; he will forfeit clear vision rather than disturb it. The plus lens power which is added will therefore focus the emergent rays in front of the mirror. and the reflex move "against."

But if the patient be hyperopic, the accommodation-convergence ratio will be abnormal, accommodation being in excess. If artificial

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plus lens power be now supplied, the eye will accept the help, and surrender an equivalent amount of its accommodation, so that the reflex will remain neutral. This acceptance and surrender will continue down to the point where normal accommodation-convergence relation is

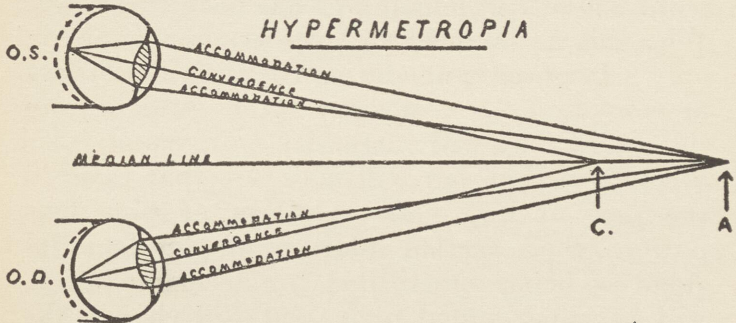

Fig. 5. Showing relationship between accommodation and convergence in hyperopia. (From Cross.)

reached. Beyond that point the eyes will not surrender any more of their accommodation in return for lens aid. Any further addition of plus lens power will change the reflex motion to "against." The amount of lens power thus accepted and substituted for accommodation represents the true refractive error, including any latent error, if present.

Let us assume that the patient is 2 D. hyperopic. The mirror and the fixation object are held 50 cm. from the eyes. This demands 4 D. of accommodation, 2 D. for the distance and

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2 D. for the hyperopia. But it requires only 6 diopters of convergence, or a ratio of 3:2 with the accommodation, whereas the normal ratio is approximately 3:1. If plus lens power be now supplied, the eyes will accept the help, and surrender their accommodation, down to the point where 2 D. lens power has been furnished. With this assistance, the eyes are now exerting only 2 D. of accommodation for their 6 diopters of convergence,—a normal ratio,—and beyond this point they will surrender no more of their accommodation, but will maintain that ratio in the face of any more addition of plus lens power. Such further addition of plus lens, instead of being substituted for accommodation, will be super-added to it, and will change the reflex from neutrality to an "against" motion. The error is computed at 2 D., i. e., the amount of plus lens power which sufficed to bring accommodation and convergence into comfortable ratio.

It is understood, of course, that the 3:1 ratio between accommodation and convergence is only an approximate, average one; more probably, an ideal one, which rarely, if ever, obtains. It varies in different individuals; and one of the common mistakes which have vitiated the practice of dynamic skiametry in the past has been the cut-and-dried acceptance of the mathematical 3:1 ratio. It also varies at varying fixa-

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tion distances, especially in adults and elderly people, for the reason that from early youth there is a progressive hardening of the crystalline lens (eventually producing presbyopia) which necessitates a progressively increasing effort of accommodation, over and above the sheerly mathematical increase,—a condition which does not influence the convergence, at least to anything like the same extent.

However, each individual does undoubtedly have his own comfortable point of accommodation-convergence relation, at various fixation distances. This relation does, in the majority of normal people, lie somewhere around the 3:1 ratio. It is impossible to treat the subject definitely without assuming *some* such average ratio. With this understanding, we shall assume the 3:1 ratio in describing and calculating the findings of dynamic skiametry, throughout this book,—bearing always in mind that it is simply an arbitrarily agreed upon figure.

It will be readily seen that, if Cross' assumptions be granted, this method affords a means of including in our measurement of hyperopia whatever part of the error may be latent (ciliary spasm) such as we cannot attain by static skiametry. Such latencies rarely exceed 1 D., and almost never exceed 2 D., so that by making our dynamic test at appropriate distances the latent error is taken care of by what Cross

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aptly terms "absorption," i. e., it is included in the active accommodation in force during the test.

Suppose, for example, we have a patient who is 4 D. hyperopic, of which 1 D. is latent. By static skiametry, at whatever distance, with

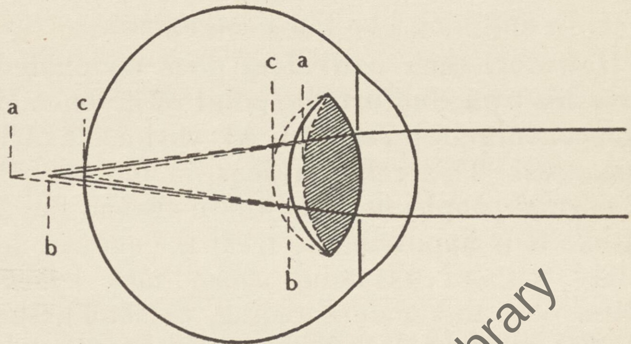

Fig. 6. Showing how a ciliary spasm is "absorbed" in the total accommodation in force during dynamic test. (From Cross.)

the working lens in place, it will take a 3 D. convex lens to neutralize the reflex, and the error will be erroneously computed as 3 D. of hyperopia.

Now let us see what would happen under dynamic skiametry. At a fixation distance of 50 cm. the patient would be forced to exert 6 D. of accommodation,—2 D. for the distance and 4 D. for his hyperopia, the 1 D. latency being

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included in the latter. The convergence for this distance is 6 diopters, for which, the normal accommodation is 2 D. According to Cross' assumption, then, this patient would continue to accept plus lens aid and surrender his accommodation until the latter had been reduced to 2 D. and would there stand pat. But, as he began by exerting 6 D. of accommodation, this would require the acceptance of 4 D. plus lens power, thus disclosing his total error, including latency.

It is, however, quite evident that Cross' theory fails to take into account some important factors in the accommodation-convergence equation. It is necessary to mention only the more important and obvious of these.

1. Cross' theory assumes that convergence is wholly, or at least uniformly, stimulated by accommodation, whereas in fact this is not the case. A considerable proportion of it is stimulated by the fusion sense; and this proportion is no means a constant quantity.

2. It does not take into account the phenomenon of relative accommodation.

Both of these objections derive added weight from the fact that, while dynamic skiametry is an objective mode of measuring the refraction of the eye, it has in it a very decided and important element of subjectivity, namely, the fixation of the vision on a chart, or at least

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upon an object, at a near point,—which immediately and intensively brings into play the subjective faculties of the patient's mind. It is only by his reading of the test letters, or by his clear and single vision of the test-object, that we can know that he is properly fixing at the test-distance. And such an effort imposes a powerful stimulus both on the fusion faculty and on relative accommodation.

3. Clinical experience has demonstrated, over and over again, that where dynamic skiametry has given a larger hyperopic finding than static retinoscopy, and distance correction has been given in accordance with the former, with a view to developing the supposed latent error, no latent error has developed. In the early days of dynamic skiametry, when Cross' theory was accepted at its face value, practitioners were in the habit of giving full distance correction in accordance with the dynamic finding, notwithstanding it fogged the patient badly, believing that in a little while the uncoving of the spasm would adjust the correction to the vision. In a large number (perhaps the majority) of cases, however, this happy outcome did not eventuate; patients came back to have their glasses changed, or they went elsewhere and were lost to the dynamic practitioner; and so the practice was abandoned, and with it, unfortunately, the whole dynamic

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method was in many instances discredited.

The probabilities are, therefore, strongly against the completeness of Cross' working theory; and we understand that even Cross himself, in later years, no longer held to his specific interpretation of his test, which, nevertheless, remains a most valuable procedure. The truth is, there is considerable difference of opinion as to the proper interpretation to be placed on the role and the findings of dynamic skiametry, even among those who are most expert in its employment. Sifting this varied opinion out, we may, perhaps, classify it into three principal groups:

1. The followers of Cross still continue to hold the general view that the dynamic finding indicates the full distance correction, but not necessarily the correction which can or should be given the patient. It represents, in fact, the limit of ciliary relaxation in any individual case, in much the same way that a finding under a cycloplegic does. The objection to this view is that it has but little clinical value. All that it affords the practitioner is a hint of the probable, or possible, extent to which the patient may be expected to accept plus correction in the course of time,—all of which, however, has still to be worked out from time to time.

2. A more modern group of refractionists regard dynamic skiametry as a valuable method

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of demonstrating and working out conditions of accommodative efficiency. They make a distinction between accommodative insufficiency and accommodative inefficiency. The former is, of course, presbyopia, whether normal or premature; the latter means that the ciliary muscle is not properly innervated. The conditions in question will be discussed at length a little later. According to this view, the excess plus finding of the dynamic over the static test represents the ciliary deficiency in that particular case for the distance at which the dynamic test is made.

Under this interpretation, the dynamic test is essentially a near-point test, and would not be used as the basis of a distance correction. It would be a question for the operator's judgment whether he would prescribe reading correction to help the inefficiency disclosed by the test, or not, the answer depending upon the results of other investigation.

3. A third group, instigated and headed by Charles Sheard, believes that dynamic skiametry as taught by Cross is principally a quick and sufficiently accurate method of determining the negative relative accommodation of the eyes, i. e., the range of accommodation they can be forced to surrender without changing convergence. From such a viewpoint dynamic skiametry assumes the highest practical value. It becomes an excellent method of determining

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the reserve accommodation power of the eyes, and the flexibility of the accommodation-convergence function; and it also affords a means, as Cross held, of finding the point at which accommodation and convergence are most normally and comfortably related.

The apparent discrepancy between these different viewpoints is, as we shall presently see, chiefly a difference of working method and technic.

Relative Accommodation

The crux of dynamic skiametry is, without doubt, the relationship between accommodation and convergence. The crucial question, therefore, is: What is the nature and extent of this relationship?

The truth is, there is an association between the two, and at the same time they are independent of each other. No intelligent interpretation of their joint or separate phenomena, no correct solution of their clinical problems, is possible without a clear understanding of this seemingly paradoxical truth. Here, undoubtedly, lies the essential weakness of Cross' original theory and application of his system; and here, without doubt, is to be sought the key to its real meaning and value.

There can be no question that there is normally a definite physiological association between accommodation and convergence, con-

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cerning which the following can be postulated:

(a) They are normally exercised together, in a definite ratio.

(b) This average ratio is mathematically expressed in terms of lens and prism diopeters, respectively, as approximately 3:1.

(c) One function is normally stimulated by the other.

It is not necessary, for the purposes in hand, to determine the precise nerve-muscle mechanism by which this associated action is brought about; it is, indeed, impossible, since no conclusive data are available. It is not even material to this particular issue to point out Savage's thus far uncontroverted dictum that "Whatever may be true of other associated brain centers, it appears that the center of the ciliary muscles and the convergence center can have associated impulses run in only one direction, that is, from the former to the latter,"—so that convergence can rarely, if ever, induce accommodation. The net facts remain as stated in the above postulates.

If these were *all* the facts, then, to be sure, Cross' assumptions concerning the phenomena and findings of dynamic skiametry would be obvious,—and, incidentally, many other oculo-refractive problems would be greatly simplified. But, unfortunately for such simplification, they are not. As Zoethout pertinently

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says, "very few of the so-called laws in physiology are laws of the Medes and Persians,—indeed, adaptability is the great distinction between the animate and the inanimate world."

It is true that the act of accommodation is regularly accompanied by the act of conver-

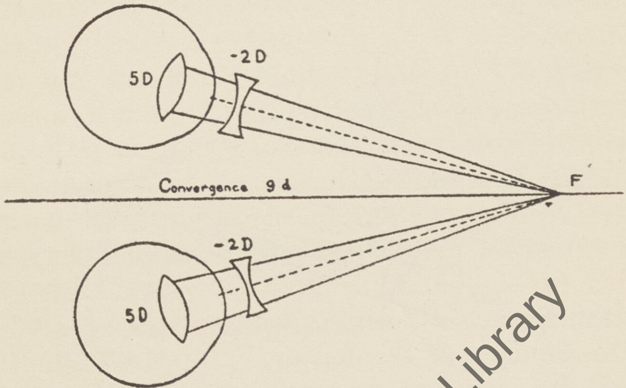

Fig. 7. Illustrating positive relative accommodation. Under the influence of minus 2 D. lenses the eyes increase their accommodation from 3 D. to 5 D. without changing their 9 d. of convergence.

gence. It is also true that there is normally a certain quantitative ratio between the two, which may be approximately given as 3:1,—diminishing as the near point is approached. But it is always possible, by means of minus lenses, to force a certain amount of accommodation at any given fixation point without altering convergence; and by means of plus lenses to sup-

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press a certain amount. These forced and suppressed quantities are known, respectively, as positive and negative relative accommodation. The sum of the two is said to be the relative accommodation of the eye.

Similarly, by means of prisms, base out and

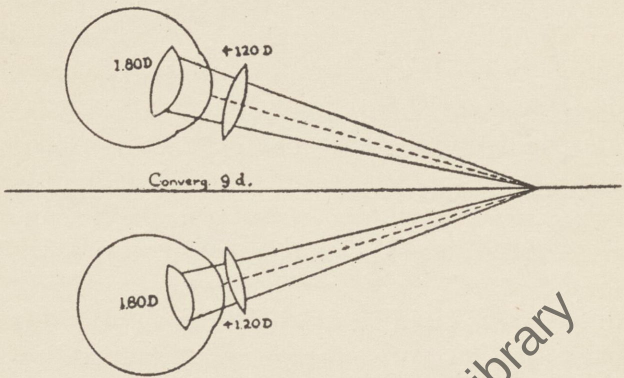

Fig. 8. Illustrating negative relative accommodation. Under the influence of plus 1.20 D. lenses the eyes surrender their accommodation from 3 D. to 1.80 D. without changing their 9 d. of convergence.

base in, a certain amount of convergence can be forced and suppressed, respectively, without affecting the accommodation, known as relative convergence. The actual happening in this case, to be sure, is not the same as in relative accommodation, since the eyes are not actually made to converge any more or any less, but maintain their original fixation. Physiologically, however, the result is analogous, for

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the maintenance of fixation against the influence of the prisms calls for increased and decreased innervation of the internal recti, respectively, proving that convergence is to this extent independent of accommodation.

It is due to this latitude of relative accommodation that every ametrope is not doomed to strabismus and amblyopia. For if the ratio between the accommodation and convergence were a rigidly fixed quantity, every ametrope would be obliged to choose between two alternatives,—either to see distinctly but double, because of defective convergence, or else to see singly but indistinctily, because of defective accommodation.

This relative amplitude of accommodation has its limits, of course. A hyperope of a certain degree may succeed, with an effort, in achieving the excess accommodation demanded by his refractive error while maintaining emmetropic convergence. But if for any reason it should become easier to disregard the image of one eye than to maintain relative accommodation, then he is likely to lapse into squint. Or if the amount of refractive error be greater than can be compensated by relative accommodation, then the patient usually chooses the other alternative, namely, to see singly but indistinctly; or, rather, he gives up trying to see clearly at all, just as the high myope does.

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Total and Proportional Relative Accommodation

Several attempts have been made to determine the average amounts of positive and negative relative accommodation possessed by normal eyes, and exercised at various points of fixation. Perhaps the most widely accepted table, in this country at all events, is that published by Dr. Lucien Howe, in his "Muscles of the Eye," Volume I, which is here reproduced, based upon a total accommodative amplitude of 8 D. From this table the author has plotted a set of curves, showing the relation between the two phases, showing the convergence in meter angles as abscissae and the maximum convex and concave lens power overcome at various convergence points as ordinates, which is also reproduced here.

Table of Relative Accommodations

Meter Angles	Accommodation	— Glass Overcome	Total Relative Acc.	Actual + Accommodation	+ Glass Overcome	Actual — Acc.
0	0	—3.25	2.95	0	0	2.95
1	1	—3	2.59	+0.75	0.72	3.31
2	2	—3	2.44	+1.5	1.38	3.82
3	3	—2.5	1.95	+2.0	1.74	3.69
4	4	—2	1.46	+2.25	1.85	3.31
5	5	—1.5	1.06	+2.50	1.90	2.96
6	6	—1.0	0.71	+3.25	2.34	3.05
7	7	—0.75	0.51	+4.5	3.08	3.59
8	8	0	0	+5.5	3.61	3.61

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Despite the difference shown in this table and curve, it seems fairly certain that in any individual the sum of the positive and negative

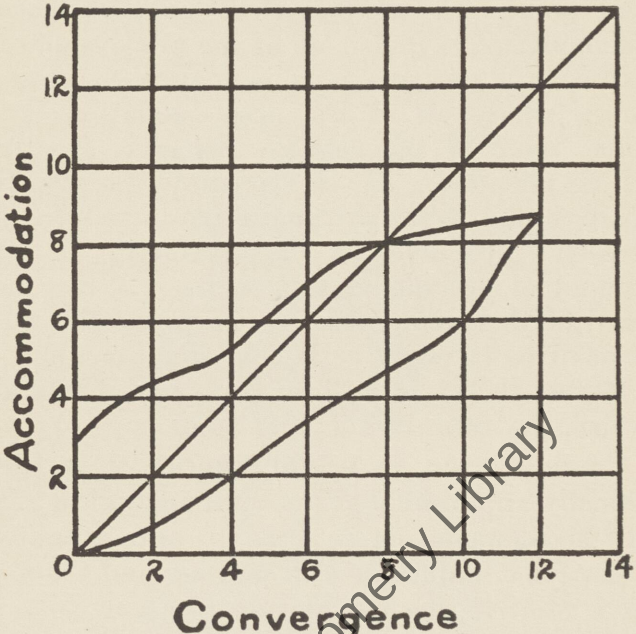

Fig. 9. Howe's chart of curves of relative accommodation, plotted on convergence abscissae. (From "Muscles of the Eye," by Lucien Howe, M. D., G. P. Putnam, New York.) Acknowledgments are due to G. P. Putnam's Sons Co. for permission to reproduce.

relative accommodation is *theoretically* the same for any given fixation point. That is to say, the total relative range is a fairly constant quantity, to be forced or surrendered on de-

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mand. The proportion between the positive and negative complements necessarily varies inversely as you run the gamut from far to near point. At infinity, where none of the accommodation is in use, all of the relative accommodation is positive, none is negative. At near point, where all of the accommodation is in force, none of the relative range is positive, all is negative. At intermediate points, the positive and negative ranges are inversely and directly proportional, respectively, to the amount of accommodation in use. When one-third of the accommodation is in use the ratio of positive to negative is 2:1; when one-half is in force, the ratio is 2:2; when two-thirds are in use, the ratio is 1:2; and so on.

Coming down to actual figures, it is theoretically apparent that the total amount of relative accommodation is equal to approximately 40% of the amplitude still unused, and the negative relative accommodation to about 40% of that which is in use. In practice we shall find that these proportions are modified somewhat by other factors.

This estimate applies, of course, only to normal accommodative quantities, that is to say, to accommodative quantities which are normal to the distance for which they are exercised. The eyes can surrender, under plus lens forcing, 40% of 2 D. at 50 cm., 40% of 1.50 D. at 26

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inches, and so on. What the ranges of relative accommodation are in excessive or deficient accommodation for the given distances would necessitate an indefinite number of experiments to determine; and even then, the results would probably be far from uniform. Practically, however, we are concerned only with the normal ranges. A patient who is using excessive accommodation for a given distance will naturally accept lens power in lieu of accommodation down to the place where his accommodation is normal for that distance. Such acceptance and surrender need not be regarded as an act of relative accommodation. Being now rendered normal for the distance in question, he can be made to surrender 40%, or thereabouts, of his normal.

Convergence keeps step with this progressive sequence. What is true of accommodation is also true of convergence, namely, that not more than about 40% of its total amplitude can be comfortably sustained. So that the limit of sustained convergence coincides with that of sustained accommodation. Beyond that point, both are difficult to maintain,—difficult in combination, equally difficult independently. That is to say, beyond that point it is hard to sustain normal accommodation-convergence, and equally hard to exercise relative accommodation or relative convergence.

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Accommodative and Fusional Convergence

It has been established by repeated experiment that all of the convergence exercised at a given point is not the result of accommodation stimulus, but only a part of it. The remaining portion is the result of direct stimulus by the fusion center. How much of the convergence is due to each of the two stimuli is still a moot point. Sheard, who has probably done more investigation of the subject than any other one man, puts the proportion, in normal cases, at 2 parts accommodative to 1 part fusional. But it must be quite apparent to anyone who knows anything about physiological variations that no hard and fast ratio can be assumed, even in normal cases. Certainly the proportions vary greatly whenever refractive or muscular defects upset the normal balance between accommodation and convergence; and we cannot safely assume that the variations keep mathematical step with the discrepancies between the two functions. Sheard is convinced that the closer the near point is approached, i. e., the more intensive the demand for convergence becomes, the greater is the stimulative part played by accommodation, and the less (in proportion) is the fusional stimulus. If this be true of the normally increased demand caused by shorter distance, then it is probably also true in abnormal cases where the increased demand

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arises from muscular imbalance or anomalies.

Sheard further believes, and the facts bear him out, that the fusional stimulus acts as a supplemental agent, making up, by its additional stimulus, whatever is lacking in accommodative convergence to achieve single binocular vision. This being granted, it follows that whenever the accommodative stimulus is too powerful, inducing excessive convergence, the fusion center acts as an equalizer, suppressing the excess. Whether it suppresses it *in potentia* or *in esse,* i. e., whether it suppresses the desire to converge and withholds innervation from the internal recti muscles, or whether the internal recti are innervated to contraction and then counteracted by an equal innervation and contraction of the external recti, is a question that cannot be definitely answered. The probability is that in some cases the former course is followed, and in other cases the latter.

The "Flexibility" Factors

The exploration of a patient's relative accommodation is of the highest practical importance, because it represents what is known in engineering as the "flexibility" of the function. It is not supposed that an automobile will be called upon, under ordinary conditions, to make such a low speed as 5 miles an hour, or such a high speed as 90 miles an hour, without disturbing the other mechanical adjustments of

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the car. But the fact that it *can* do so, on demand, gives it the necessary "flexibility" to insure its doing 50 to 60 miles an hour, steadily, continuously, without strain, and without upsetting other adjustments. And the measure of this flexibility is the precise measure of its capacity to sustain its regular performance. In the same way, the flexibility of the muscular mechanism of vision, i. e., its relative accommodation and convergence, is the measure of its capacity to sustain steady, comfortable vision at its customary working point of fixation.

If, then, it can be shown that dynamic skiametry furnishes an objective means of exploring and determining this flexible element at the patient's working distance, we have in dynamic skiameter a highly valuable method of refraction.

All of the above-noted facts concerning relative accommodation must be taken into consideration in the application and interpretation of dynamic skiametry,—and more. For the chief value of the test is, after all, not to explore normal but abnormal cases. And if one or more of the factors involved be out of alignment, it is easy to see that that discrepancy will upset the entire mechanism.

If, for example, the patient starts out, at infinity, with a portion of his accommodative

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amplitude already in use, but with none of his convergence in force, there will be a disturbance all down the line, to near point, not only between accommodation and convergence, but between the positive and negative complements of his relative accommodation, and between the accommodative and fusional elements of his convergence. The general nature and extent of this disturbance may be roughly shown by a comparison between the two following tables:

NORMAL

(Accommodative Amplitude 10 D.)

Dist.	Accom.	Converg.	Rel. Accom. Pos.	Rel. Accom. Neg.	Converg. Accom.	Converg. Fusional
Inf.	0	0	4.00 D.	0		
2 meters	.50 D.	1.50 d.	3.80 D.	.20 D.	1.00 d.	.50 d.
1 meter	1.00 D.	3.00 d.	3.60 D.	.40 D.	2.00 d.	1.00 d.
50 cm.	2.00 D.	6.00 d.	3.20 D.	.80 D.	4.00 d.	2.00 d.
33 cm.	3.00 D.	9.00 d.	2.80 D.	1.20 D.	6.00 d.	3.00 d.
12.5 cm.	8.00 D.	24.00 d.	.80 D.	3.20 D.	16.00 d.	8.00 d.

2 D. HYPEROPIA

(Accommodative Amplitude 10 D.)

Inf.	2.00 D.	0	3.20 D.	.80 D.	4.00 d.	—4.00 d.
2 meters	2.50 D.	1.50 d.	3.00 D.	1.00 D.	5.00 d.	—3.50 d.
1 meter	3.00 D.	3.00 d.	2.80 D.	1.20 D.	6.00 d.	—3.00 d.
50 cm.	4.00 D.	6.00 d.	2.40 D.	1.60 D.	8.00 d.	—2.00 d.
33 cm.	5.00 D.	9.00 d.	2.00 D.	2.00 D.	10.00 d.	—1.00 d.
12.5 cm.	10.00 D.	24.00 d.	0	4.00 D.	20.00 d.	4.00 d.

It is here estimated that accommodation stimulates twice its own amount of convergence in prism diopters. In hyperopia, therefore, the fusion sense often has to correct excess, as indicated by the minus sign.

By laying a rule under corresponding horizontal lines in

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the two tables, the difference in the sets of conditions for that fixation point will be seen at a glance.

Even these tables, dramatic as they are, still come far from representing the actual conditions. Like all mathematical attempts to express a physiological state of affairs. they are too beautifully perfect to be true. They assume at once too much and too little. According to their showing, for example, one has only to add a plus lens to the hyperopic eye, and presto! the rest of the formula becomes immediately and automatically righted. They leave out of the reckoning all muscular anomalies, perverted muscle-nerve habits, spasms, fusional deficiencies, and other functional troubles which always complicate the situation in clinical actuality, and which cannot be written into a mathematical formula.

Anomalies of the extrinsic muscles form a subject of study and practice all their own, too large to be gone into here. It is a subject, however, closely allied with dynamic skiametry, and one cannot be intelligently practiced apart from the other. A few of the less commonly considered anomalies of accommodation will here be briefly mentioned.

Accommodative Insufficiency (Presbyopia)

This condition is, of course, physiological at and after middle age, when it goes by the name of presbyopia. It is only when it is found in

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younger persons, and when in presbyopes the insufficiency exceeds the amount proper to their age, that it is regarded as an anomaly, and is commonly spoken of as accommodative insufficiency, or subnormal accommodation.

In physiological presbyopia the chief cause of the deficiency, as everyone knows, is the hardening of the crystalline lens, which prevents it from assuming the necessary convex curature. In cases of true premature prebyopia, occurring in young people and even in children, the same cause is assignable. In both these classes it is to be borne in mind that the insufficiency is one of *results* and not of *effort.* Such a patient, focusing for a given distance, is actually exerting more effort, and using more accommodative innervation than the normal,—a point of important significance, as we shall presently see, in the interpretation of dynamic skiametry in these cases.

There is, however, another class of accommodative insufficiencies in which the insufficiency *is* one of effort or innervation. It is a little hard to draw a hard and fast line in these cases between insufficiencies due to actual paralysis, complete or incomplete, and those due to functional derangement. Some, to be sure, belong to the former class, and are then to be regarded as medical cases. Others belong just as definitely in the purely functional class, where no

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lesion exists, but the trouble is in a faulty innervation of the muscle. Still others form a sort of borderland group (e. g., neurasthenia) in which it is hard to say whether the trouble is functional or toxic,—perhaps a mixture of both. In a large proportion of cases it seems impossible to assign any definite cause at all.

The prime symptom, naturally, is an inability to see at a convenient near point—premature, or (in the case of an older person) excessive presbyopia. The near point, as in a ciliary spasm, is usually normal. Investigation shows a contraction of the accommodative range, and diminution of the amplitude. Tests for ciliary spasm reveal none. Relative accommodation is either lacking or much reduced. Attempts to force accommodation fail. There is, however, no trouble until the patient's near point is approached.

Accommodative Inefficiency

This condition is to be carefully distinguished from the former. Its existence and importance is of comparatively recent recognition. It consists, essentially, not in any lack of muscular or nervous power, but in an inability to coordinate them properly. Many persons, for some reason or other, never achieve their own potential near point; others never attain a comfortable relative coordination between accommodation and convergence, and therefore cannot (or do not)

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hold a near point long when they find it. Apparently no definite cause can be assigned. It seems to be simply a faulty habit of functioning.

These are the cases which, above all others, call for thorough investigation of the accommodation-convergence relation, positive and negative relative accommodation, and accommodative reserve, and whose treatment taxes the judgment of the refractionist. Needless to say, accurate distance correction, where needed, is of great importance; although, to be sure, many of these cases of inefficiency are found in emmetropes. Emmetropia being present, or being brought about by distance correction, inefficient accommodation must be acknowledged when a patient proves to have normal amplitude but cannot use it at working point without strain.

As to the treatment of such cases, that is a matter of exceedingly nice judgment for the refractionist. They need some kind of help. No doubt the best kind of assistance, if practicable, is indirect assistance, which will induce proper coordination between accommodation and convergence. But, if necessary, the refractionist need not hesitate to give reading glasses.

The situation in regard to accommodative inefficiency is well summed up in the late R. M. Lockwood's formulary:

1. The accurate functioning of accommoda-

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tion depends upon a perfectly balanced innervation of the ciliary.

2. Emmetropia is merely zero of ocular refractive measurements, and has no relation to ciliary innervation.

3. There are no sure methods of detecting faulty ciliary innervation at a distance.

4. It is readily detected at near point by several methods,—the best being dynamic skiametry and the cross-cylinder test.

5. Glasses, to be comfortable, must be such as to bring about balanced ocular innervation.

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CHAPTER III

DEFINITION OF DYNAMIC SKIAMETRY

We are now in a position to attempt something like an intelligent definition of dynamic skiametry,—what it is, and what it is capable of doing.

The definition of any such procedure is manifestly to be approached through an observation and interpretation of its findings under normal conditions. Let us first see what Cross has to say on this point:

"When an eye looks at an object situated 40 inches away, it must exert its accommodation to at least 1 D. Place a plus 1 D. lens over this eye, and if it is emmetropic the emergent rays will focus at 20 inches. 1 D. will then represent the accommodation and 1 D. the trial lens, or artificial myopia, making a total of 2 D. If a plus lens of 2 D. is used, the point of focussing will be at 13 inches; if a plus 3 D., it will be at 10 inches; the accommodative myopia increasing the artificial myopia."

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The trouble with this statement is that it does not define with sufficient accuracy the conditions and events; and it is this very looseness of definition that injects confusion into Cross' theory, and invalidates many a dynamic test.

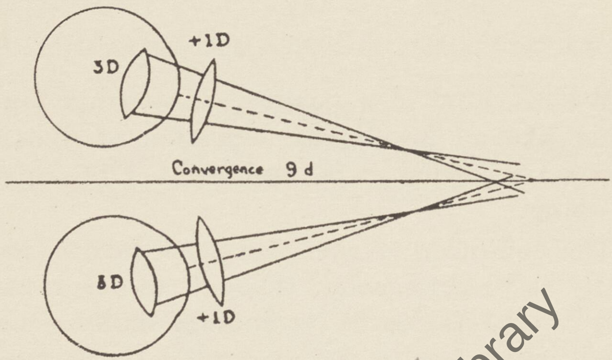

Fig. 10. Illustrating how the interposition of a plus 1 D. lens before normal eyes reverses the emergent waves, and therefore the skiametric reflex, under the simple fixation method. The eyes maintain their comfortable accommodation convergence relation.

What actually happens in the case cited above depends entirely on the conditions observed. When the emmetropic eye is fixed and focussed on an object at 40 inches, its accommodation is, as Cross says, 1 D., and its emergent rays focus at the 40 inches. And (as he omits to say) its convergence is 3 d., i. e., in normal ratio with the accommodation. So far so good. Now

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place a plus 1 D. before this eye, and *one of two things* will occur.

If the patient be instructed to maintain mere *fixation* of the object, that is to say simply a single image of it, without being particular as to clearness of detail, then the sequence of

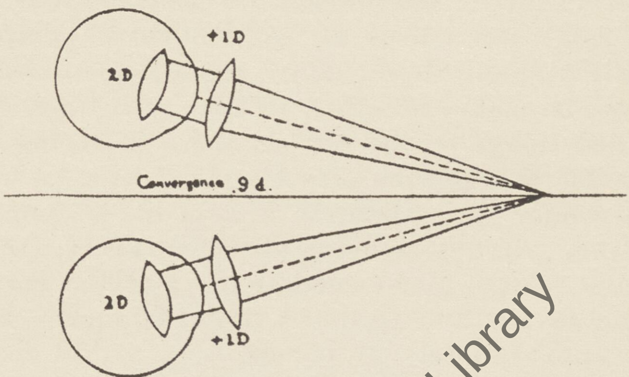

Fig. 11. Illustrating how the interposition of a plus 1 D. lens before normal eyes does *not* reverse the emergent waves, or the skiametric reflex, under the fixation-focussing method. The eyes surrender their negative relative accommodation, thus preserving the dioptric values of the emergent waves.

events will be as Cross has described them,—the emergent rays will be focussed at 20 inches. For in that case the eyes will, of choice, maintain the normal, comfortable relation between accommodation and convergence, namely, 1 D. accommodation and 3 d. convergence, and the plus 1 D. lens will be superadded to the 1 D. of

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accommodation, producing a total of 2 D. myopia. Under the same conditions, if a 2 D. plus lens be used, the focussing point will be at 13 inches, as described by Cross. And so on, down the line.

But if, instead of instructing the patient to merely "fix" the object, we instruct him to "focus" it; that is to say, instead of simply maintaining a single image, regardless of clearness, he makes an effort to keep a distinct, detailed image of the object; then, in trying to do this through the plus 1 D. trial lens, he will surrender approximately 40% of his accommodation, without changing his convergence, (negative relative accommodation), and the emergent rays will be focussed, not at 20 inches, but at approximately 21 inches, i. e., at the focal length of 1 D. (trial lens) plus .60 D. (his accommodation, less 40%), a total of 1.60 D. If 2 D. lens power is used, the same thing holds good, and the focussing point will be at approximately 15 inches. And so on.

It all depends, then, upon the difference between "fixing" and "focussing." And that, in turn, depends upon whether the desire for a clear, detailed image, or the desire for comfortable accommodation-convergence relation, dominates the subjective element of the test. The latter, to be sure, is the more instinctive desire, and will no doubt prevail provided no positive

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incentive is furnished to stimulate the other; but the desire for a clear, detailed image, on the other hand, is a very powerful one in the presence of any object that excites curiosity, and is especially powerful in the case of an ocular test, where the patient is usually obsessed with the idea that he is *expected* to get a detailed view. The situation can be controlled, by means of the technic, concerning which we shall speak in a subsequent chapter. The point just here is that it *must* be controlled if we are to get the results and the interpretation we are after. We must distinguish between fixing and focussing.

The Accommodative "Lag"

Sheard believes, from a long series of tests by various skiametric methods, that there is always a "lag," skiametrically considered at least, of the accommodation behind the convergence. By this he means, "that eyes practically emmetropic as far as any static or subjective tests could determine, possessed of plentiful amplitude of accommodation, fusion powers, and reserves,—in other words, as nearly physiologically perfect as could be found,—have demonstrated the fact that small convex lens quantities are always accepted skiametrically, fixation and observation being in the same place. These convex quantities," he adds, "usually remain constant, irrespective of the

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distance of the fixation point, and amount to practically one-half to three-quarters of a diopter before neutrality of the shadow is obtained.'' He designates this as a normal lag of accommodation.

In short, Sheard points out that in dynamic skiametry the skiametric point of reversal is always a little further, and its dioptric value therefore a little less, than the patient's fixation point and its dioptric equivalent.

The practical result of this state of affairs, of course, is that all dynamic findings will be slightly greater at close points in hyperopia, and slightly less at close points in myopia, than the static retinoscopic findings.

Other authorities, while recognizing the difference shown in the static and dynamic findings, disagree with Sheard as to its significance and explanation. James P. C. Southall, of Columbia University, in an article published in the Journal of the Optical Society of America, September, 1926, entitled ''The Optical Theory of Skiascopy,'' makes the following statement:

''To take a specific instance, let us suppose that the examination is being purposely conducted at a distance not much greater than the average normal distance of distinct vision for near work, say 13 inches (or about one-third of a meter), and that the patient is required to fixate a target at this distance and to distin-

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guish clearly certain minute details on it. Under such conditions it is practically invariably the case that the skiascope will indicate a decided movement 'with the mirror,' and in order to find the point of reversal the distance between the two eyes has to be slightly increased without altering any of the other conditions. Various hypotheses, more or less ingenious, have been offered to account for the neutral region and to explain the apparent discrepancy between theory and practice which has always been something of a stumbling block in the way of dynamic skiametry. Thus, for example, it has been suggested with much show of reason that the difficulty that is encountered here in this particular instance is due to a certain lag of accommodation behind the convergence of the two eyes, so that the measurement would really amount to a determination of one portion of the amplitude of relative accommodation for a given degree of convergence. The trouble with this explanation is that exactly the same result is obtained with the skiascope when the illumination is dim and the patient fixates with the illuminated eye while his other eye is completely screened.

"The writer is persuaded that the true explanation of the whole matter is to be sought in the monochromatic aberrations of the human eye, and that, admirable and useful as the ordi-

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nary method of skiascopy is for the determination of refraction, it should always be checked and supplemented by subjective methods of measurement. Gullstrand's mathematical and stigmatoscopic investigations of the complicated form of the caustic surfaces in the case of a bundle of rays that have traversed the dioptric system of the eye (as described, for example, in Chapter V of the appendix of Volume 1 of the English translation of Helmholtz's Physiological Optics) show that with a pupil of moderate size the place or section of most advantageous convergence of the bundle of rays for distinct vision is quite appreciably different from cusp of the caustic surface where the so-called paraxial rays are focused. In fact, his measurements indicate a difference of focus on account of aberration which in the case of an emmetropic eye with pupil of moderate size may amount to as much as 1.5 dioptries of hypermetropia along the axis. Consequently, in his very careful calculation of the schematic eye, Gullstrand has compensated for the effect of aberration by allowing a certain average value of one dioptry; in other words, the refraction of the unaccommodated schematic eye must be equal to one dioptry of hypermetropia in order that it shall be equivalent to an actual emmetropic eye under the same conditions. Now in the optical theory of skiascopy as developed

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above no account whatever was taken of the effect of aberration. The so-called focus plane was defined simply as the plane conjugate to the surface of the retina; which would be identical with the transversal plane conjugate to the cusp of the meridian section of the caustic surface, if the cusp itself were situated on the retina. But since this cusp is not after all the most advantageous place of convergence of the rays for distinct vision, the focus plane will not coincide with the plane on which the eye is fixated, that is, the plane of the target on which the patient is able to see the details distinctly. When the mirror is adjusted in the latter plane, it is natural to expect, therefore, that there will be a movement of the reflex exactly as is found to be the case. When the eye is accommodated for comparatively near vision, the change of focusing required to shift the retina, figuratively speaking, from one section of the bundle of refracted rays to another closely adjacent section may easily amount to as much as a dioptry or more. Consequently, the whole reason for the confusion that has been the subject of so much controversy, especially in connection with dynamic skiametry, and for the apparent discrepancy between theory and practice would seem to be due to the unjustifiable identification of the so-called focus plane with the plane of the actual target on which the eye is fixated.''

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Fay McFadden, of Rutland, Vt., who has made some thoughtful contributions to the subject of dynamic skiametry, offers several logical theories for the explanation of the static-dynamic discrepancy:

1. Faulty fixation by the patient, due to:
   (a) Poor fixation targets.
   (b) Brightness of the mirror light, insensitizing the eye.
2. Aberation of the optical system of the eye.
3. Coma of the reflex.
4. Location of the origin of the "crest" of the reflex on the surface of the choroid rather than on the surface of the retina, creating a different dioptric effect skiametrically to that of the eye, amounting to about .50 D.

In Sheard's justification it must be pointed out that his "accomodative lag" was an expression in terms of a finding, rather than an attempt to express the cause. His important service consisted in calling attention to the finding, which for the present must be accepted and reckoned with in the practice of dynamic skiametry while we continue to seek for its true explanation.

The fact remains that the discrepancy between static and dynamic findings does exist; and, as Sheard wisely says, the only correct

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procedure in obtaining the relative negative accommodation objectively is to determine experimentally by some skiametric procedure the lense quantity necessary for reversal, and to subtract therefrom about .50 D. in cases of hyperopia, and to add thereto about .50 D. in cases of myopia.

This writer, while he believes that more than one cause probably contributes to the phenomenon, is inclined to accept the explanation suggested by Professor Southall; and if this be accepted, then the discrepancy must be ascribed to either or any method of skiascopy as applied to the dynamic eye.

Seeing that, whatever explanation is accepted, the effect or result is in the nature of a "lag" of the accommodative finding behind the convergence, this term will be used, for convenience, throughout this book in referring to the discrepancy in question.

The Two Methods

It appears, then, that there are two separate and distinct operations and interpretations of dynamic skiametry, according to the method and technic employed.

1. It determines the point of comfortable working relation between accommodation and convergence, thereby, in most instances, also determining the refractive correction to be worn at that point.

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2. It measures the negative relative accommodation at the point of observation, thus furnishing a valuable means of exploring this flexible element of vision in its various relationships.

To Dr. Joseph Pascal, of New York, must be given the credit for perceiving and pointing out this dual method and significance of the test. Cross believed and taught that the first of these was the true purpose and meaning of his system; but his error lay in the fact that the method and technic which he used were such as to arrive at the second. Sheard long ago called attention to the excessive plus findings of the Cross methods, (attributed by Cross to latent hyperopia, spasm, etc.), and showed that what Cross was actually doing by his method was to measure, objectively, the patient's negative relative accommodation. Sheard himself considered, and we understand still considers, that he obviates Cross' error by substituting neutrality for reversal in the test. He adds his plus lens power to the bare limit of *neutralizing* the reflex, instead of *reversing* it, and holds that this amount of lens power represents the refractive needs of the eye at the point in question.

It is difficult to understand, however, wherein this substitution of neutrality for reversal alters the working principle of the test, or, in

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fact, does anything more than to arbitrarily reduce the amount of the finding by just as arbitrarily stopping short of the full result. What the test actually measures does not depend upon where one stops testing, but upon what the patient's eye is doing under the conditions of the test. Sheard's method and technic are essentially the same as those employed by Cross, namely, fixation and focussing, and if by this means Cross was inducing relative negative accommodation, so is Sheard; and the fact that Sheard stops as soon as neutrality is reached, while Cross carried on to reversal, means only that Sheard measures something short of the patient's full negative range while Cross probably measured something in excess of it.

It would seem, therefore, that the whole confusion which has attended the performance and interpretation of dynamic skiametry since Cross' day must be laid to the confusion between purpose and method,—which it remained for Pascal to clear up.

So far as the first definition is concerned, it needs little or no enlargement. It is relatively simple in principle, although not always so simple in practice. Whatever difficulties it involves are difficulties of detail.

In its second definition, dynamic skiametry is not so simple, either in principle or in interpre-

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tation. It is beset with many intricate factors, which influence one another and the whole, all of which have to be reckoned with in giving value to the dynamic findings.

A comparison between the two methods in a given case of abnormal refraction may be made from the following illustrations:

Patient is an adult of about 40 years of age. By the first method, fixating at 40 inches, the reflex is found to be neutral. Instructing him to maintain fixation but not focussing, we find that it takes a plus 2.00 D. to reverse the reflex. When we come in to 13 inches, the reflex changes with a plus 2.25 D. lens. Subtracting .50 D. for the lag, this means that at 40 inches he is using 1.50 D. more accommodation than he should normally use, and is to that extent out of accord with the 3 d. of convergence necessary for that distance. At 13 inches he is using 1.75 D. excessive accommodation, and is still out of harmony with his convergence. He accepts lens help, in each instance, down to the point where his accommodation for the distance is in normal relation with his convergence. The interpretation of the test is that he is a 1.50 D. hyperope.

Now apply the other method. With the eyes fixating and focussing at 40 inches, we find the reflex neutral as before. Instructing the patient to maintain a clear, detailed image of the object, we find that we are able to put up a plus

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2.40 D. before the reflex changes. Subtracting .50 D. for "lag," the reversing lens is plus 1.90 D. The normal accommodation for this distance is 1 D., of which 40% or .40 D. is negative relative accommodation, and must be deducted from the total lens power in order to determine the lens power which rendered the eye normal for distance in question. Subtracting .40 D. from 1.90 D. leaves 1.50 D. We therefore conclude, again, that the patient is a 1.50 D. hyperope.

Which method is the better in clinical practice?

There is no open-and-shut answer to this question. The intelligent refractionist cannot say, "I will choose this or that method, and will practice it exclusively." It depends altogether on the purpose for which he makes the test. So far as the comparatively technical accuracy of the two methods is concerned, the fixation-focussing method is probably the more exact. At any rate, it is under the more accurate control. When the patient is instructed to maintain a clear, detailed image of the fixation object,—e. g., to read fine type letters,—it is certain that he will make a positive effort to do that very thing, and we can arrange means of assuring ourselves that he is doing it. If, on the other hand, he is instructed to maintain fixation only, "letting himself go" in respect of focussing, he may or may not do it; he may

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do it completely, or he may fail completely to do it, or he may do it partially; and we have no practical means of determining whether, or to what extent, he is doing it. However, these comparative accuracies fit in with the respective purposes of the two methods, as we shall see.

Whichever of the methods is used, it is understood that dynamic skiametry is essentially a near-point test. What we are primarily concerned in discovering is the state of the accommodation-convergence function at the patient's working distance. It is, however, equally understood that our near-point finding may, and usually does, have an indirect bearing upon our distance finding, if only as a comparative check upon it. Furthermore, there are cases in which we are content to determine, in a simple and approximate fashion, the comfortable point of working relation between the patient's accommodation and his convergence at the distance in question,—permitting him, so to speak, passively to show us that comfortable point,—and to let it go at that. And there are cases in which it seems necessary to explore in greater detail, and with greater exactness, the interrelations of accommodation, convergence, and fusion.

In general, then, it may be assumed that, in relatively simple cases, where the purpose of

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the dynamic test is to check up the distance findings by the near-point findings, and to determine the best correction, spherical and cylindrical, for near work, the fixation method is the simpler and more rapid of the two, and yields results sufficiently dependable and accurate for the purpose; especially if the findings obtained under this method are such as to indicate a plain, straightforward state of affairs, corresponding fairly well with the showings of static retinoscopy and the patient's general record,—even to the extent of uncovering a latent error.

Where, on the other hand, we propose to make a detailed and searching investigation of the whole question of the patient's flexible resources, such as have been previously discussed, then we should say that the fixation-focussing method is preferable. Not only is it preferable, in that it involves a more positive, and therefore more accurate, exercise of the accommodation, but it actually gives us data concerning the relative range of accommodation which cannot be obtained by the fixation method alone, and which are necessary to the investigation we are undertaking.

Consideration of the Fixation-Focussing Method

It is apparent that with this method the sheer amount of lens power required to neutralize the reflex does not in itself represent the refractive

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error; far less does it indicate the lens correction to be worn. There are several factors still to be taken into account.

In the first place, as we have seen, when the patient makes an effort to maintain a clear, detailed image of the object, the plus lens power furnished him takes him always beyond the point of surrender necessary to attain comfortable accommodation-convergence relation. Down to that point, in fact, the fixation-focussing test is identical in behavior and result with the simple fixation test. But when the point of normal accommodation for the distance in question has been attained, the accommodative effort required of the patient enables him still to surrender from 40% to 45% of this normal accommodation, which represents his normal negative relative range at this distance. This percentage of normal accommodation at the test-distance must, therefore, always be deducted from the reversal lens power in order to arrive at the refractive error.

If the patient is shown to be exercising, let us say, 6 D. of accommodation at 13 inches, it is evident that there is a wide discrepancy between his accommodation and his convergence. We do not yet know what influence, if any, this discrepancy has upon the relative accommodation, and so upon the estimation of his error.

But we have still another thing to consider.

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In the hypothetical case cited it is plain that the accommodation stimulus of 6 D. is calling for 18 d. of convergence. But only 9 d. are in force, or the patient would see double. The inevitable conclusion is that the fusion sense is either suppressing or antagonizing 9 d. of the accommodative convergence,—at all events equalizing this amount in some effective way. Every bit of convergence in force, therefore, is accommodative convergence. Whether this, again, has any influence upon the relative accommodation, and so upon our ultimate findings, we have still to inquire.

All of these points must be reckoned with in an intelligent evaluation of the dynamic test by this method,—to say nothing of correlative data, including those of the muscles, to be gathered from other tests.

We may safely say, then, that dynamic skiametry by the fixation-focussing method, affords a valuable means of exploring:

(a) The range and behavior of the negative relative accommodation.

(b) The working relation, at near points, between accommodation and convergence.

(c) The relation between accommodative and fusional convergence.

Variations

Now, if each of these elements of vision were a constant, the application and interpretation

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of this method would be an exceedingly simple and exact affair. Or if either one of them was a constant, it would be relatively easy, by means of dynamic skiametry, to determine that one, and from it to deduce the state of the others.

But there is no evidence that any one of these elements is a constant. On the contrary, all clinical evidence points the other way. It is almost certain that, in cases of abnormal refraction at all events, no one of them is alike in any two individuals, and highly probable that no one of them is alike in the same individual at different times. The best that can be done with any of them is to establish an approximate average of normality; and that being done, too much reliance should not be placed in it. The table of averages is no more to be accepted as true for the individual in any of these matters than is the table of averages amplitudes of accommodation for the various ages. And just as, previous to dynamic skiametry, most of the mistakes in correcting presbyopia were due to the blind acceptance of the amplitude table, so most of the errors in the use of the dynamic test come from an equally fatuous acceptance of the published averages in these functional relationships.

Do these facts discredit dynamic skiametry by the fixation-focussing method? By no means. The same considerations apply to muscle tests,

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and, in fact, to every method of examination which involves muscle-nerve action; yet we do not condemn or abandon these procedures on that account. No such tests are capable of exact mathematical interpretation; yet they are highly useful, even indispensable, and give invaluable working data. The only danger in their use lies in assuming that they are mathematically exact, or that they yield information which they cannot possibly yield. With an intelligent understanding of the conditions they explore, a proper sense of their limitations, and a careful correlation of their findings with those of other tests, they become invaluable aids in the diagnosis and management of many cases.

So it is with the fixation-focussing method of dynamic skiametry. As stated, it affords a useful means of exploring the three flxible elements in vision,—the relative accommodation, the accommodation-convergence harmony, and the accommodative-fusional stimulus. True, none of them is a mathematically constant factor; but each has some sort of an approximate average form, to which the vast majority of individuals conform, within the limits of individual variation, and from which any marked departure suggests a clue to their visual troubles.

A few of the principal factors which probably modify the constancy of the elements in

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question may here be briefly considered:

We have assumed, as a working hypothesis, that the normal range of relative accommodation is approximately 40% of the accommodative amplitude, and that the negative complement of this range, at any given fixation point, is about 40% of the accommodation-in-force. That is to say, in plain language, an individual can normally surrender about 40% of the accommodation he is using at any fixation point. In actual practice, however, this is probably modified by other factors.

It is perfectly apparent that, so far as relative accommodation is concerned, the fusion sense is the equalizer that makes it possible. Whatever accommodation is surrendered below the required stimulus to convergence, fusion must supply the deficiency; and whatever accommodation is forced above that demand, fusion must suppress the excess; in order to maintain convergence in *status quo*. Sheard estimates (probably correctly) that in emmetropia and orthophoria about one-third of the convergence exercised is fusional, but that the nearer one approaches to near-point, the greater proportion is accommodative.

We know that on demand the fusion sense is perfectly capable of negotiating *all* of the convergence, for myopes habitually converge for near-points without a vestige of accommoda-

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tion to stimulate the act. But we know, too, that their convergence is very unstable, and surrendered on far less provocation than accommodative convergence,—as witness the myope's excessive exophoria. It may well be true that a similar discomfort and imbalance attends the opposite state of affairs, i. e., too small a proportion of fusional, and too large a proportion of accommodative, convergence.

At all events, experience shows that as soon as we get into the region of near-fixation, where accommodative convergence is noticeably in excess of its proper proportion, and fusional convergence drops below its normal ratio, relative accommodation becomes greater; as though that ratio were harder to maintain than the regular 3:1 ratio. In hyperopia, of course, this state of affairs is much more pronounced, for here, in most cases, at near point, the accommodative stimulus is considerably in excess of what is needed, so that fusional stimulus is acting negatively, i.e., suppressing or antagonizing convergence. It is almost certain that under such conditions the equalizing effort of fusion induces a readier surrender of accommodation than in emmetropia.

It can hardly be doubted, then, that the proportional complements of accommodative and fusional convergence have a decided influence upon the amount of accommodation the eye can

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surrender, i.e., upon negative relative accommodation, since fusion, as pointed out, is the equalizer that makes such surrender possible. It would not be surprising, indeed, to discover that the fusion element determines, and perhaps is actually responsible, for the relative range of accommodation in each individual.

Still another factor which must modify relative accommodation is the tonicity and duction conditions in the extrinsic muscles. The harder it is to maintain muscular balance, from whatever cause, the more likely it is that the break in relations between accommodation and convergence follows an abnormal course. One would naturally assume that in hyperopia, where the tendency is toward espohoria, the eyes would surrender their accommodation more readily—which is in line with Cross' own theory, though with a different explantion. This, again, makes it probable that the amount surrendered by the hyperope under the dynamic fixation-focussing test is more than the theoretical 40% of the normal accommodation.

Finally, there is always the possiblility that we are dealing with a functional or paralytic insufficiency of accommodation, or with accommodative inefficiency, which, as we have intimated, vitiates every phase of the dynamic test, by whichever method, unless and until it is recognized.

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In the light of these considerations we may enlarge a little upon our definition of what dynamic skiametry by the fixation focussing method may be expected to do.

It measures the relative negative accommodation at the fixation point under investigation. But the negative relative range which it discloses cannot be assumed to be the theoretical 40% of the normal accommodation. The nearer it is to normal, the more likely it is to approximate the theoretical 40% proportion; the further it is from normal, the more likely it is to be more or less than 40% of the accommodation-in-force. In the latter event, no final estimate of the actual refractive error can be based on the finding until it has been checked up with the factors which influence it—fusion, muscular imbalance, distance error, and the like.

It also discloses, or at least implies, something of the working relations between accommodation and convergence, and between accommodation and fusion stimulus. But these, again, cannot dependably be given their face value. They, too, must be checked up against other data.

Presbyopia

The same principles apply to presbyopia, so far as dynamic skiametry is concerned, as to hyperopia, although the phenomena differ

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somewhat. By the simple fixation procedure we seek to induce the eyes to find their comfortable point of relationship between accommodation and convergence. Here, however, it is important to bear in mind that by "accommodation" we mean *accommodative effort* rather than actual focussing. That is true, to be sure, in any case. The accommodation-convergence

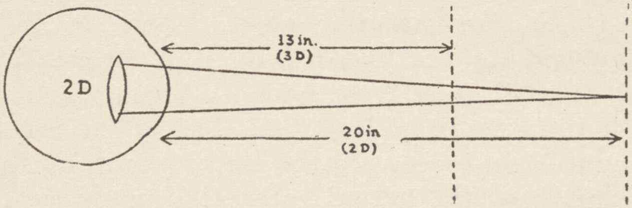

Fig. 12. Illustrating insufficiency of accommodation (presbyopia) for a 13 inch distance. The eye is only able to exert 2 D. of accommodation, and therefore to focus only for 20 inches.

relation is between the physiological accommodative effort and convergence effort, not between the results accomplished by the two functions—far less between two mathematical expressions of their results. In non-presbyopic cases, however, the effort and the result are so nearly equivalents of each other that one may be considered in terms of the other; but in presbyopia they are so far from being equivalents that to regard them as such is false and misleading.

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The hardening of the crystalline lens imposes on the presbyope the necessity of exerting more effort for less result than the normal individual. This, also, is to a certain degree true of every adult, since the lens begins its hardening process early in adult life. But not until it noticeably reduces the accommodative amplitude does it seriously influence our measurements and calculations. It is, in short, when this point is reached that presbyopia exists.

Clinically, presbyopia begins when the diminished accommodative amplitude no longer permits of comfortable sustained vision at near working distance. A person whose accommodative amplitude has fallen to 6 D. is already presbyopic for 13 inches, because at that distance he is obiliged to use one-half of his amplitude, and this is too large a proportion to be comfortably sustained. Such a patient may be said to have relative presbyopia. When the amplitude falls below 3 D., then it is impossible for the patient to focus at 13 inches at all. Such a patient is, for that distance, absolutely presbyopic.

This, however, by no means tells the whole story. Not only is the person with a 6 D. amplitude obliged to enforce one-half of his amplitude for focussing at 13 inches (which is bad enough), but in order to negotiate the 3 D. accommodative *result* he is obliged to make con-

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siderably more than a 3 D. *effort*. There was a time when his amplitude was 12 D. It is fair to assume that the same disability (the hardening of his crystalline lens) which has halved his amplitude has doubled his effort for any given distance. Probably more, but at least that. If, when his amplitude was 12 D., he had enforced half of it, he would have focussed at 6.66 inches. It is certainly fair to assume that with an amplitude of 6 D. when he focusses at 13 inches he uses as much accommodative *effort* as formerly gave him a 6.66 inch focus—that is to say, 6 D. of effort.

The truth is, of couse, that the relation between effort and result in these patients cannot be standardized or assumed. It differs in different individuals and under different collateral conditions. Hence the futility of prescribing for presbyopia from any table or formula, and the value of dynamic skiametry, which determines, not result, but effort.

The point is that the accommodative *effort* of the presbyope, not its results in accommodation diopters, is the factor in the accommodation-convergence relation. If a presbyope is accommodating for 13 inches (i.e., 3 D. of result) and is using 6 D. accommodative effort to do it, he is just as truly out of harmony with his 9 d. of convergence as though he were actually making 6 D. of accommodation. His 6 D.

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accommodative effort is stimulating 18 d. of convergence, which his fusion must suppress. And he will accept lens assistance, surrendering accommodation in exchange for it, down to the point where his accommodation *effort* is in comfortable relation with his convergence. Just when and where that point will be reached in any given patient, no man, as we have said, can mathematically calculate. But it will determine itself under dynamic skiametry by the simple fixation method, for beyond that point the presbyope, like the hyperope, will decline to accept any further lens aids or to surrender any more accommodation, and the reflex will change to an "against" motion. The acceptance and surrender are, of course, enhanced by the heavy proportion which the accommodation-in-force bears to the total amplitude.

The actual behavior of the eyes under the test may be described as follows. We are for the present assuming distance emmetropia.

If the presbyopia be absolute, i.e., if the patient be quite unable to focus the target at the plane of the mirror, but can by an effort focus a plane beyond it, there is, of course, no neutral reflex. The reflex has a "with" motion at the outset. With the first furnishment of plus lens power, the eye will surrender some of its effort —so much of it, in fact, as is represented by

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its effort-equivalent of the lens-power—so that presently (perhaps with the first trial lens) it is able to focus the mirror, whereupon the reflex will become neutral. Thereafter, the eye will continue to accept plus lens power, surrendering accommodation effort in exchange therefor, until that effort is reduced to comfortable relation with the convergence, whereupon any further addition of plus lens power will produce an "against" movement of the reflex.

If the presbyopia be relative, i.e., if the patient is able, by an effort, to accommodate for the observation distance, there will be fixation and focussing of the object and therefore a neutral reflex from the start. Otherwise, the developments of the test will be the same as above described.

The fixation-focussing method does not lend itself well to the measurement of presbyopia. For while negative relative accommodation is just as truly an affair of innervation and accommodative effort as the phenomenon we have just been considering, yet it is virtually impossible to measure relative ranges except in terms of dioptric results; and where effort and results are so widely different as in presbyopia, reliable caluculations of the former cannot be made from the latter.

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The method to be employed in presbyopia is the simple fixation method.

Summary

The extensive applications of dynamic skiametry may be briefly summarized in the following enumeration. We may say that in general dynamic skiametry can be used.

(1) To find the lens that best correlates the commodation and convergence by producing the most comfortable adjustment between these two functions at any given distance.

(2) As an extension of the above, it can be used to find the presbyopic addition for insufficiency of accommodation.

(3) As a further extension of (1), it can be used to diagnose inefficiency of accommodation in the young and to find the lens aid required for near work.

(4) It can be used as a guide for the probable presence of latent hyperopia or latent muscular inbalances.

(5) It can be used for finding the amplitude of accommodation monocularly and binocularly, by finding objectively the near point of accommodation.

(6) It can be used to test for equality of accommodation between the two eyes, as to quantity or quality.

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(7) It can be used for finding the relative accommodation, both the positive portion and the negative portion. But as was said in the opening paragraphs, the rationale and technique for each of these uses is more or less specified and applicable to that particular use.

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CHAPTER IV

GENERAL TECHNIC

In the clinical application of dynamic skiametry two general questions arise:

1. Shall the test be made with the plane of the mirror as the point of fixation, or with the point of fixation at one distance and the observation point at another?

2. Shall the patient's distance correction (if any) be before his eyes during the dynamic test, or shall the latter be made on the unaided eye?

Question No. 1 would seem to be one of technical convenience and accuracy, rather than of working principle. Some hold that it is impossible for a patient to read letters on a chart, or otherwise properly fix an object, and have an observable point of reversal at another distance. The present writer, however, agrees with Sheard that this criticism is unwarranted, provided certain technical conditions are fulfilled—chief of which is that the fixation object shall be as nearly as possible in the same horizontal and lateral plane as the pupillary center, so as to involve the minimum amount of conjugate movement of the eyes. So long as this

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is the case, the fixation point can be somewhat further or nearer than the observation point without seriously impairing the accuracy of the shadow.

The fixation point may, for example, be at 40 inches, and the reversal sought and found at 26 inches. For, as Cross points out, the "ray values," i.e., the distances of fixation and observation, have their lens equivalents, which can readily be calculated and either added to or subtracted from the neutralizing lens. Suppose the fixation point be at 40 inches and the observation made at 26 inches, and it takes a plus 2 lens to reverse the reflex. The lens equivalent of 40 inches is 1 D., that of 26 inches is 1.50 D., the difference between them .50 D. We have then, only to add this .50 D. to the 2 D. neutralizing lens to obtain the actual reversing power, namely, plus 2.50 D. If the two distances be reversed, the fixation point being at 26 inches and the observation point at 40 inches, then the .50 D. must be subtracted instead of added.

The advantage of this method lies in its convenience, as it enables the operator to maintain one position throughout the test, moving his fixation object forward or backward to change the patient's accommodation. Its disadvantage consists in the fact that it involves several measurements of distance, which are likely to be too inaccurate for purposes of exact refrac-

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tion, especially when the distances to be measured are so near to the eye, where even small errors of distance mean considerable differences in lens power. For this reason, most experienced practitioners prefer to employ the method of simultaneous fixation-observation.

On Question No. 2 there are also arguments *pro and con.* Cross' original method was to shadow each eye, *as is,* without any distance correction in place. But Cross, of course, regarded dynamic skiametry as a means of measuring distance refraction. Since this view has been virtually abandoned, and the dynamic test recognized as essentially a near test, the practice has become prevalent of carrying it out with the patient's distance correction (previously ascertained by static retinoscopy) in place. Those who do so argue, with some show of reason, that the near correction will eventually be worn in conjunction with the distance correction, and that it is therefore the accommodation-convergence resources of the eyes under those conditions that we have to investigate by our dynamic test.

In spite of this argument, and notwithstanding Sheard approves and (we believe) practices it, we are not in agreement with the method. The distance refraction should, to be sure, be measured by static retinoscopy in advance, for comparison with the results of the

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dynamic test. But, as we see it, the very essence of the dynamic test lies in the assumption that at near distances, where muscular and nervous efforts are in active force, accommodation-convergence defects (if any) are more manifest and more thoroughly detectable than at the far point, where one at least of the functions is passive. For this reason, we believe that the dynamic test should originally be made upon the naked, unaided eye, and afterward, perhaps, checked up with the distance correction in place.

To the two questions just discussed may be added a third:

Shall the dynamic test be monocular, or binocular, or both? That is to say, shall each eye be shadowed with the other eye excluded from vision, or with both eyes jointly engaged in fixation, or both?

There can be no question that, so far as the dynamic test itself is concerned, it is a binocular test. Sheard believes that in every dynamic test an investigation should be made (a) of the separate accommodative powers of each eye, apart from convergence, by monocular tests, and (b) of the convergence powers of the eyes, apart from accommodation, by muscle and fusion tests. But this, of course, is not an argument against the binocular character of the dynamic test. It is a plea for additional investi-

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gation, to obtain all possible data for comparison and consideration in arriving at a final prescription.

It goes without saying that the state of the extrinsic muscles should be investigated by duction and fusion tests. Without such muscular data it is impossible to interpret intelligently the findings of dynamic skiametry. But the different accommodative resources of the two eyes (if they are different) can doubtless be satisfactorily determined, in the great majority of cases, by testing each eye separately while both are engaged in active binocular vision.

At any rate, whatever additional tests are made, the ultimate dynamic test *must* be made binocularly, i.e., each eye must be shadowed while both are fixing. For practical purposes, therefore, it is probably best that the binocular test be made at once ("eventually—why not now?") and the nature of the findings left to decide whether or not it seems advisable to supplement it with a monocular investigation as suggested by Sheard.

Having disposed of these preliminary points, we can now proceed to a general description of the technic of dynamic skiametry. Special technic, including detailed steps, lighting, equipment, etc., will be treated in a separate chapter. We will first describe the general technic of the

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simple fixation method, the method of Cross:

Assuming that the simultaneous fixation-observation method is to be employed, the patient is seated as for static retinoscopy, the operator sitting opposite him in a chair or on a stool so adjusted that it will bring his eyes into approximately the same horizontal and lateral plane with those of the patient.

The skiascope is applied to the operator's eye as nearly as possible 40 inches from the patient's face, as determined by methods to be described in the next chapter, and the patient is instructed to fix his eyes on the chart, or other fixation object, attached to the top of the mirror or to the operator's brow, so as to get a clear, single image.

Having obtained a good fundus reflex, tilt *not* the mirror but the head, with the mirror held firmly against the cheek and brow, very slightly to and fro, as in static skiametry, and observe the movement of the reflex. If it moves against the mirror, advance a little toward the patient; if with, draw back a trifle; until the neutral point is found. Assume that it is approximately at the 40 inch distance.

Now begin to place plus lens power before the patient's eye, beginning with very low power and gradually increasing it. Instruct the patient to keep his eyes fixed upon the target, so as to maintain a single image, but not

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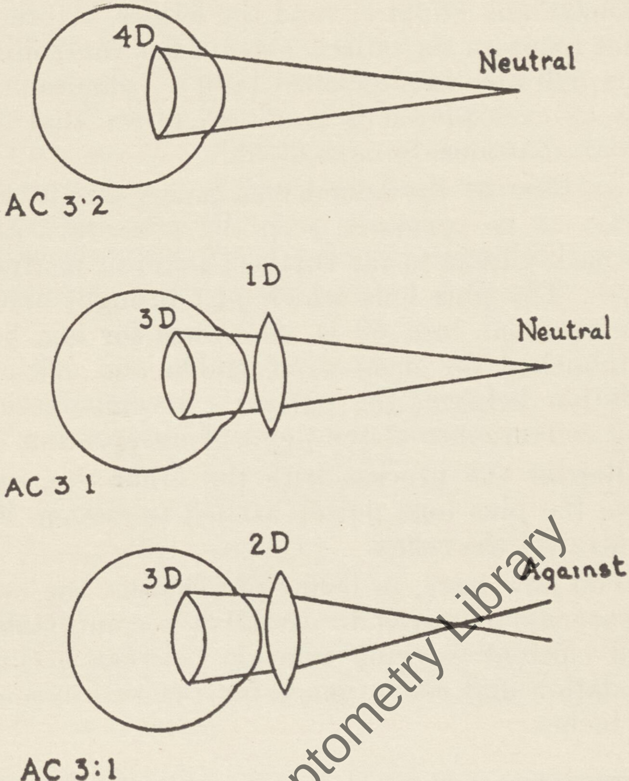

Fig. 13. Illustrating the modus operandi of the simple fixation test, in the case of 1 D. hyperopia. In the upper diagram the eye is exerting 4 D. accommodation for a 13 inch distance; the reflex is neutral. In the second diagram, the eye has surrendered 1 D. of its accommodation under the aid of a plus 1 D. lens, and is now in comfortable accommodation-convergence relation; reflex still neutral. In the lower diagram the eye refuses to surrender any more of its accommodation, and the 2 D. lens reverses the emergent waves, giving an "against" motion of the reflex.

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to make any effort to read the letters, or otherwise focus on the object. (Means for controlling this will also be described later). Shadow the eye as each plus lens is added, to see that the reflex continues to be neutral.

As soon as the added lens power causes the reflex to be reversed, stop the procedure and go back a little to the furthest point of neutrality.* The plus lens which just brought about the reversal, less .50 D. allowance for lag, has established the most comfortable and efficient relation between the patient's accommodation and convergence at the point of observation.

Repeat the process with the other eye, and note the plus lens power needed to change the neutrality the reflex.

You now have, in terms plus lenses, the necessary aid required to establish a comfortable and efficient working relation between accommodation and convergence for the two eyes at 40 inches.

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*The only way of telling when the eye has reached the limit of surrendering its accommodation is to overstep that limit with the plus lens power, and force a reversal of the reflex to an against motion. The lens power which does this is, of course, a trifle more than the actual requirement of the eye for correction. The proper technic in every instance, therefore, is to put on plus lens power until the reversal is just brought about, and then to "back up" a little, or reduce the plus power a bit, until the precise limit of neutrality is found. It is to be assumed that this is what is intended, throughout this book, whenever the term "reverse" or "reversal" is used.

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Repeat the entire process at 13 inches, and note the findings at that distance.

If the two sets of findings agree with each other, allowing for the different distances, and if they agree substantially with the distance findings under static test, they are probably correct as they stand.

The dynamic test can now be repeated at the distance for which the patient desires specific

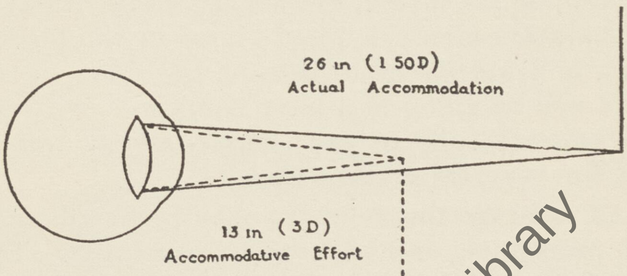

Fig. 14. Illustrates the discrepancy between accommodative effort and actual accommodation in presbyopia. This eye is making a 3 D. effort, which ought to focus it at 13 inches, but is only achieving a 1.50 D. result, which focusses it at 26 inches.

help, i.e., the distance at which his occupation requires him to use his near vision, and working correction prescribed accordingly, giving him lenses for the two eyes, respectively, of the strength represented by the lens power which just reversed the reflexes.

We now turn to the fixation-focussing method.

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With the patient and operator seated as above, at a distance of 40 inches, tilt the mirror as before, and ascertain the point of neutral reflex, which we will assume to be approximately at the 40-inch distance.

Now begin to place plus lens power before the patient's eye, beginning again with low power and gradually increasing it. In this case, instruct the patient not only to keep his eyes fixed upon the target, but also to make an effort to maintain clear, detailed vision of the object, e. g., to count irregular dots on the chart. (Details will be given in a later chapter.) Shadow the eye carefully as each lens is added, watching for reversal of the reflex.

As soon as the reflex is just reversed, stop the procedure, and back up to neutrality. The plus lens which has just brought about the reversal of the reflex, less .50 D. for lag, represents the patient's excess accommodation for the 40 inch distance, plus his negative relative accommodation at the same distance, i. e., 40% of 1 D., or .40 D. Subtracting this .40 D. from the trial lens, therefore, will give you the patient's excess accommodation at 40 inches.

Repeat the process with the other eye, and note the plus lens power needed to just reverse the reflex.

Repeating the process at 13 inches, the negative relative accommodation and the excess ac-

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commodation can be similarly determined for this distance—except that at 13 inches the relative range must be figured as being a little more than 40% of the accommodation-in-force—perhaps 45%.

Again, if the findings are substantially in agreement, allowing for the distance factors, with each other and with the static test, they may be regarded as being frank, straight-forward indications of the near-point conditions. The test can be repeated again at the patient's working distance, and correcting lenses prescribed.

If, however, the case is known beforehand to be complicated with other troubles, or if the dynamic test shows it to be "suspect" by the unsatisfactory results, then of course the completion of the dynamic test, as just described, is but the initial step to a series of investigations of the accommodation, muscle and fusion functions, whose results must be correlated with the dynamic findings in deciding the ultimate state of the case and its correction.

A hypothetical case, examined by the two methods, will perhaps serve to illustrate the comparative findings of the tests and their interpretation.

Let us assume that the patient is a young adult with good accommodative amplitude, who

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has been shown by static retinoscopy to be a distance hyperope of 1.50 D. Under the simple fixation method, suppose that it takes a plus 2 D. lens to just reverse the reflex at 40 inches. Subtracting .50 D. for lag, this means that 1.50 D. adjusts the relation between accommodation and convergence at this point. At 13 inches it takes perhaps a trifle more than 2 D. to change the reflex. Again, 2 D. less .50 D., or 1.50 D. adjusts the accommodation-convergence relation at this point. As these two findings agree with one another and (allowing for the discrepancy of .50 D.) with the static finding, it may be regarded as correct. The patient is a 1.50 D. hyperope, who needs only his distance correction of that amount for near vision.

Under the fixation-focussing method, we find that this patient requires a plus 2.40 D. lens to just reverse the reflex at 40 inches. Subtracting .50 D. for lag leaves it plus 1.90 D. The normal accommodation for 40 inches is 1 D., of which 40% is negative relative accommodation, i. e., .40 D. Deducting this .40 D. from the trial lens, gives 1.50 D. as the amount of excess accommodation at the distance in question. At 13 inches it takes a plus 3.35 D. to reverse,—less .50 D. for lag, giving plus 2.85 D. as the reversing power. The normal accommodation for 13 inches is 3 D., of which 45% is negative relative accommodation, that is to say 1.35 D.

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Deducting this 1.35 D. from the reversing power of 2.85 D. gives 1.50 D. as the excess accommodation. The conclusion is the same as by the other method, namely, that the patient is a straight 1.50 D. hyperope.

The above is, of course, a very simple case—purposely so, since it demonstrates, in simple fashion, the elementary technic and findings of the two methods. In actual practice such a case hardly needed a dynamic test, except as a matter of routine—which, nevertheless, it is well to carry out, since we have no way of knowing in advance that a simple distance refraction will be an equally simple case of near refraction, even in a young adult.

Let us now turn to a little more complicated case. Assume a patient (still a young adult) who has been shown by static retinoscopy to be a distance hyperope of 1 D., but his amplitude seems rather less than normal at his age. Under the simple fixation test it takes a plus 2.50 D. lens to just reverse the reflex. At 13 inches it takes 2.75 D. Here, allowing for the .50 D. discrepancy, we have a dynamic finding of 1 D. more than the static. The case is probably one of 2 D. hyperopia, of which 1 D. is latent and therefore not disclosed by the static test. This case, however, should not be allowed to go without further investigation—first of all, by the fixation-focussing method.

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Under the fixation-focussing method, we find that at 40 inches it takes a plus 2.90 D. to just reverse the reflex. Subtracting .50 D. for lag gives plus 2.40 D. The normal accommodation for the distance is 1 D. Deducting 40% of 1 D., or .40 D. from the reversing power of 2.40 D., gives 2 D. as the patient's excess accommodation. At 13 inches, the reversing lens is plus 3.85 D. Subtracting .50 D. for lag leaves 3.35 D. The normal accommodation for 13 inches is 3 D., of which 45%, or 1.35 D., is negative relative accommodation. Deducting this 1.35 D. from the reversing lens power of 3.35 D. gives 2 D. as the excess accommodation. As this brings out the result in agreement with the other method, and with the same excess over the static finding, we can probably assume that the case is really one of 2 D. hyperopia, with a 1 D. latency.

Careful muscle tests should, nevertheless, be made to confirm the conclusion.

Still more complicated cases will be described and discussed in a future chapter devoted to illustrative cases.

Dynamic Skiametry in Myopia

In all of the foregoing descriptions and illustrations it has been assumed that the patient's error, if any, was a hyperopic one. This was for the reason that hyperopia lends itself more

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readily to an explanation of the principles and technic of the dynamic test than does myopia. It is obvious, from the very nature of the test, which consists in substituting plus lens power for accommodation, that it is far more applicable to cases of excessive accommodation (hyperopia) than to those in which there is little or no accommodation in force to start with (myopia). Indeed, as hinted elsewhere, there is reason to believe that disturbance of the accommodation-convergence, upon which the dynamic test rests, gives serious discomfort only where the accommodation is in excess of the convergence.

Where the myope's far point is further away than the point of observation, and fixation, i.e., in low degrees of myopia, it is evident that the case will present the same phenomenon at the outset of the test as emmetropia or hyperopia. That is to say, on shadowing the naked, fixating eye, the reflex will be found neutral, since the fixation point and the retina are conjugate. If the simple fixation method be employed, the first addition of plus lens power will change it to an "against" motion, because in this case added plus power is taking the patient further and further away from his comfortable accommodation-convergence point. As in subjective and static tests, we must try the addition of minus lenses. If the case be emmetropic, the

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first addition of minus lens power will change the neutral reflex to a "with" motion, for the reason that the emmetrope will not budge from his normal comfortable relation in either direction. If it be myopia, the addition of minus lens power will still give a neutral reflex, because the patient will increase his accommodation to compensate for the trial lens.

Whether he would continue to do this, increasing instead of surrendering accommodation, up to the point of normal accommodation-convergence relation, is a moot question. It is highly improbable, for the reason already stated, namely, that deficient accommodation does not seek its normal relation with convergence as excess accommodation does. Probably the best course to pursue, having discovered that the case is one of myopia, and being still desirous of examining it dynamically, is to force it into hyperopia by means of large minus lens power, and then shadow with plus lenses as we would a case of hyperopia.

If the fixation-focussing method is used, the low myope will, on the addition of plus lens power, exercise his negative relative accommodation, the same as a hyperope or an emmetrope. But, necessarily, his negative range will be small, since he had a subnormal amount of accommodation-in-force to begin with, and he cannot surrender more than 40% of that. On

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the other hand, his positive relative accommodation, if tested by minus lenses, will be unusually large.

Where the myopic far point is inside of the working distance, it is obviously impossible to obtain a neutral reflex from the start. The motion will be "against."

In any case, however, high or low degree, the supposed existence of myopia will have been previously shown by the static and subjective tests, which ought always to precede the dynamic. The sole question then to be determined by the dynamic test is whether or not this statically-determined myopia is really myopia, or latent hyperopia. This is very quickly discovered, because, if it is a latency, the eyes will behave under the dynamic test precisely as hyperopic eyes would be expected to behave under it—as described in the foregoing portions of this book. If, on the contrary, it turns out that the static diagnosis of myopia was correct, there is little or nothing of value to be derived from the dynamic test. Muscle and fusion tests should always be carried out in such cases, for in these respects myopes are usually defective.

Aside from the above, the chief value of the dynamic skiametry in myopia is the determination and measurement of astigmia.

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Dynamic Skiametry in Astigmatism

The uses and interpretations of the dynamic test hitherto considered have assumed only spherical errors, which, of course, have directly to do with the accommodation-convergence function. Its use in the detection and measurement of astigmatic conditions is quite another matter. Here the principle and method are practically the same as in static retinoscopy, except that the shadowing is done upon an eye with some of its accommodation in force. Yet, curiously enough, whatever may be thought of the peculiar value of the dynamic test in other respects, there is no question of its superiority in cases of astigmia, giving far more accurate results and avoiding several of the common sources of error which pertain to the static method, such as large pupils (spherical aberration), scissor-movements, etc.

Perhaps the most important point in the dynamic test for astigmia is the difference so frequently disclosed in the direction of the principal axes as compared with the static finding. Sheard asserts that the axis shown by the dynamic test agrees with the showing of the ophthalmometer much more constantly than does the axis shown by the static test. However this may be, it is certain that the dynamic test frequently reveals a different axis from that shown by static retinoscopy; in most such

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instances, a slightly oblique axis where the static test has shown a right one; and that the axis revealed by the dynamic test usually proves to be the one accepted by the patient and comfortably worn.

Sheard believes, and this writer agrees with him, that the difference in finding connotes an actual difference in the curvature due to the tonal condition of the muscles, extrinsic or intrinsic or both, during the dynamic test, which is lacking under the static procedure. Ciliary tone, to be sure, is not altogether lacking, even under the static test, in cases of hyeropia; and it would be interesting to know whether, in cases of high compound hyperopia, the proportion of oblique axes disclosed by static retinoscopy is greater than in low degrees of error. However, in the common run of cases it is certain that even the ciliary tone is considerably less under the static test than under the dynamic; and extrinsic tone, which has most to do with astigmatic axes, is usually quite absent.

An interesting consideration arises here. If the static test shows an astigmia with its axis vertical, and the dynamic test reveals the axis at 75 deg., and if this discrepancy represents an actual difference in the meridians of curvature when the eyes are at rest and when they are in action, does it not follow that a cylinder placed at the proper axis for near vision would be out

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of place for the correction of distant vision, and *vice versa?* The answer inevitably is, Yes, it would. And, so far as this writer's opinion goes, it is highly questionable if a prescribed cylinder ever does give accurate correction for both near and distant vision in any case of astigmia.

For practical purposes, however, we are saved the necessity of splitting hairs over this hypothetical question. The practical truth is that nobody ever uses his infinity vision for detail, save in exceptional cases, such as navigating, hunting, etc., for which special distance glasses of extraordinary accuracy are required. In small degrees of astigmia, therefore, slight off-axes are not of any great importance for distance vision. For close vision, on the contrary, accuracy of axis is of the highest importance. At any rate, and in any case, it is at near working point that astigmia assumes its real importance, and if there be an actual difference between near and distance axes, it is the former which must be given the benefit of the discrepancy.

In fine, the last court of resort is the patient's acceptance; and, as stated, the axes revealed by the dynamic test are most often those ultimately accepted for comfortable and efficient use.

The general procedure is virtually the same

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as in the static test. This is the one occasion upon which the dynamic test should be conducted with the patient's distance *spherical* correction in place, as ascertained by static retinoscopy and subjective examination. This leaves but one meridian of curvature to be measured and corrected. Many operators, nevertheless, prefer to conduct the entire test in astigmatism by the dynamic method, on the naked eye.

There is but one kind of fixation available for measuring astigmia, and that is the fixation-focussing method. The eyes must be steadily and accurately focussed at the given point, otherwise the movements of the meridianal reflexes will shift and vary, vitiating the results of the test.

"With" vs. "Against" Reflex Motions

As this writer has elsewhere frequently pointed out, there is in reality but one optical element in astigmatism. The classification of this condition into simple and compound hyperopic, simple and compound myopic, and mixed, is merely one of nomenclature, for clinical convenience; and probably confuses the issue more than it helps. These qualitative differences relate, not to the astigmatic but to the spherical element in the error. So far as the astigmia itself is concerned, it consists in one single element; namely, the dioptric interval between the two principal meridians of curvature, which is

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neither myopic nor hyperopic *per se,* but simply an interval.

This being the case, there is no theoretical reason why this interval should be measured as a plus or a minus quantity in preference to the other. Theoretically, it is quite immaterial whether it be regarded as a plus interval and measured with convex lenses, or as a minus interval and measured with concave lenses. If, therefore, there is any practical advantage in one method over the other, then that is the method to be employed.

Copeland has demonstrated, as a fact of physics, that "with" reflex movements are better and more accurately observable than "against" movements. The reasons for this are discussed at some length in the chapter devoted to Optical Principles of Skiametry. It is the fact itself that is of importance here. Its clinical significance is that in determining and measuring astigmia by the dynamic method, the operator will find it to his advantage, in the interests of ease and accuracy, to convert the entire spherical element in the case, where necessary, to a plus error (including the astigmatic interval), by means of minus spheres, and then to measure the astigmatic interval as a plus quantity by means of convex lenses. By this course, he will be always dealing with "with" motions of the reflex.

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Dynamic Skiametry in Presbyopia

The existence of presbyopia, physiological or premature, is always to be suspected in the course of dynamic test from excessive plus findings at close distances. In an otherwise emmetropic person, of course, any plus finding by the dynamic test is presumptive evidence of presbyopia—although, to be sure, it may turn out to be inefficient accommodation. In a hyperope, the excess of the dynamic over the static finding, of itself, cannot be so accepted. It is just as likely, and perhaps more likely, to indicate latency, especially at 40 inches, where latencies usually show and presbyopia rarely does. But the acceptance by the patient of markedly more and more plus lenses as we move in from 40 inches to 13 and 10 inches is an unfailing sign of deficient accommodation.

The working principles involved in the test in presbyopic cases have already been explained. The general technic, down to the point where the presbyopia is disclosed and roughly measured, is relatively simple:

Proceed as in hyperopia, beginning at 40 inches. If the finding at this point is substantially the same, by either or both methods, as by the static test, the latter may be regarded as correct. If the plus finding is notably greater, the probability is that you have uncovered a latency, which the static did not disclose.

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Now come in to 13 inches. If the excess finding, as compared with the static, is about the same here as at 40 inches, it is almost certainly a latency. But if the lens power accepted at this point is noticeably greater than that which was accepted at 40 inches, before reversal occurs, it is almost certainly presbyopia—normal or premature, according to the age of the patient.

If, on coming in to 13 inches, the reflex should suddenly change to a "with" motion, then there is no doubt about the matter. The patient is unable to negotiate accommodation at 13 inches, and has an amplitude of less than 3 D.—is, in short, an absolute presbyope at this distance. Put up plus lenses until the reflex is neutralized, and continue to add plus power as long as the reflex stays neutral, until it is just changed to an "against" motion.

The amount of lens power thus accepted and exchanged from his own accommodation is the amount which reduces the patient's accommodative effort to a comfortable relation with his convergence, and is the proper correction for that distance.

The reaching of this point, in presbyopia, is a somewhat more delicate matter than in hyperopia. When the apparent point of reversal is reached, it is well to move the skiascope a little nearer to the patient's eye, and then out a little

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further again, noting the reflex, until you find the point where neutrality and reversal seem to meet.

A simple illustration of each kind of presbyopia, absolute and relative, will perhaps serve to make the matter clearer. Distance emmetropia is assumed.

1. With the naked eye under test the reflex is seen to be neutral at 40 inches. A plus lens of .50 D. is accepted without changing the neutrality. More than that gives a slight "against" motion. Coming in to 13 inches, there is, with the naked eye, a "with" motion. A plus 1 D. neutralizes the reflex. We go on adding plus lens power, without changing the neutrality, until we have added 2.25 D. in all. Then the reflex changes to an "against" motion. The patient is evidently a relative presbyope at 40 inches, and an absolute one at 13 inches, as a little analysis will show.

At 40 inches he was focussing, i.e., accomplishing 1 D. of accommodation, but apparently at an accommodative *effort* of more than 1 D., for he surrendered .50 D. in exchange for lens help, and there stood pat. At 13 inches he could not even focus; it took plus 1 D. help to enable him to negotiate this distance. After that he accepted plus 1.25 D. more (2.25 D. in all), showing that his accommodative effort was still considerably in excess of his convergence.

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2. At 40 inches, with the naked eye, the reflex is neutral, and even a plus .50 D. lens changes it to an "against" motion. At 13 inches the reflex is again neutral, but here we are able to put up plus 1 D. before it changes. It is plain that here is a relative presbyope at 13 inches. Analyzing as before: At 40 inches he was fixing and focussing, and as he refused to budge for a plus .50 D. lens, it is clear that his accommodation-convergence relation was fairly stable. At 13 inches he was fixating and focussing, but evidently with considerably more than a 3 D. accommodative effort, for he accepted plus 1 D. in exchange for some of that effort, to bring it down to comfortable relation with his convergence.

Let us now consider a case of hyperopia complicated by presbyopia.

At 40 inches, under the simple fixation method, the patient accepts plus 1.50 D. before the reflex shows an "against" motion. Under the fixation-focussing test it take a plus 1 D. to change it, i.e., he exhibits 1 D. negative relative accommodation, showing that at 40 inches he has 100/40 times 1 D., or 2.50 D. accommodation-in-force—1.50 D. too much. On coming in to 13 inches, we find that the patient's reflex is neutral to begin with, and that he accepts 2.50 D. without changing the neutrality. It is evident that this patient using 1.50 D. excess

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accommodation at 40 inches, and assuming that the static test had shown him to be that much of a hyperope, he was not presbyopic at that distance. At 13 inches, he was focussing all right, showing that, even with his 1.50 D. hyperopia he could still negotiate this distance, but even when his hyperopia had been compensated, he was evidently accomplishing the remaining 3 D. accommodation at the cost of considerably more than 3 D. accommodative effort, for he surrendered another 1 D. of his effort in exchange for lens aid before he reached a comfortable relation with his convergence. He was a relative presbyope at this point.

No case of presbyopia should ever be fitted on the findings of dynamic skiametry alone. For that matter, neither should any ametropic case. But here something a little more specific is intended. Not even the sheer focussing element of the correction should be trusted to the dynamic finding alone. Every refinement of near test, including cross cylinders, should be employed; every factor of vision, every item of data concerning the patient himself, should be obtained and weighed in the balance, before arriving at the final prescription.

Measuring the Amplitude of Accommodation

This use of dynamic skiametry has not yet obtained the wide recognition and practice that its

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importance justifies. It is the only objective means of measuring accommodation, and if only as a check on the subjective findings, it deserves consideration. Furthermore, a determination of the amplitude of accommodation is now a matter of ordinary routine in every examination. It is no longer regarded as a finding which is of importance only in presbyopic cases. And it is certainly an advantage to have for every routine test both a subjective and an objective method of determination. Both the monocular amplitude for each eye, and the binocular amplitude of the two eyes, may be measured by the dynamic method.

Sheard's Method

As previously stated, Sheard utilizes dynamic skiametry for the purpose of measuring the amplitude and range of accommodation, by determining the near point of the eye under examination.

Theoretically, this is the closest point for which the eye is capable of accommodating, and therefore the closest point at which a neutral reflex can be obtained. There are, however, certain practical difficulties in the way of carrying out the test in this simple manner. Sheard therefore substitutes the practice of approaching an object closer and closer to the eye, following it up with his skiascope, until a point is

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finally found, such that no nearer approach of the test object to the eye changes the neutral condition of the reflex as skiascopically observed at the closest point to the eye at which a neutral reflex is obtained.

The detailed procedure, as described by Sheard himself, is as follows:

The patient draws the test-object as near to the eye as will still permit of its being read. To

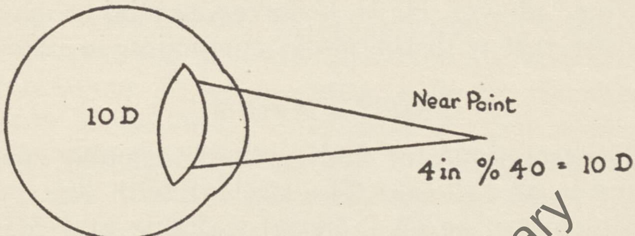

Fig. 15. Illustrates the amplitude of accommodation as indicated by the near-point. The near-point, 4 inches, divided into 40 inches, gives the accommodative amplitude, 10 D.

the observer at 13 inches the skiascope reflex will show an "against" or myopic condition, indicating that he is outside of the optical ocular far-point, dynamically considered. The operator then moves forward until he obtains a a neutral reflex. The test-object is then carried still closer to the eye (blurred image makes no difference) and the nearest point of neutral reflex found and measured. This gives the apparent near point, under whatever ocular con-

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ditions the test is made, and from it the range and amplitude of accommodation can be easily determined. We measure the distance from the pupillary plane to the mirror plane, and not from the pupillary plane to the anterior focal point.

He occasionally varies this test, and, with observation and fixation at 13 inches, produces neutralization at this point, and the proceeds as outlined above. He is, however, partial to making the test with the static correction in place.

Pascal's Method

The technique for finding the monocular near point is as follows: The patient with his distance correction on is asked to fixate and read aloud or count the letters or dots on the skiametry mirror chart. One eye is occluded and the examiner with his skiascope faces the uncovered eye directly. The fixation chart used, which must be of the fine-focussing variety, is one containing very fine type or very fine dots, or a combination of the two. A good fixation chart is one having in the center a circle of about ten mm. diameter, containing many fine dots arranged concentrically inside, and having outside the circle, scattered irregularly about a series of letters of the size of Jaeger No. 1 or 2. This chart requires exact focussing in order to comply with the examiner's requests,

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and therefore forces the accommodation to full exertion.

This chart must lie in the nodal plane of the examiner's eye. The best means of accomplishing this is to utilize a reflection of the chart in a mirror slightly back of the plane of the observer's eye. The examiner begins his test at some convenient distance lying outside the patient's near point. With patients under forty he may safely start from about 15 inches. With patients of forty and over, he may start from about 20 inches, using with the older patients an auxiliary plus 1.00 or plus 2.00 in order to bring the near point within 20 inches, and then making allowance for the lens used. With very young patients, he may even use an auxiliary minus lens in order to move the near point a little further from the patient for ease of measurement, and then allowing for the minus lens.

As the examiner begins his test beyond the patient's near point he will, on first observation, get a neutral motion. For as the patient focusses the chart in the mirror, the conjugate focus to his retina coincides with the nodal point of the examiner's eye. The examiner now moves slowly in towards the patient whose attention he keeps all the time fixed on the chart while he notes the reflex and shadow movements. As long as the patient focusses the

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chart, that is as long as the chart is beyond the patient's near point, the movements will be neutral. But as soon as the examiner gets within the patient's near point, the movement will be "with," showing the patient is focussing behind the nodal plane of the examiner's eye. The near point of accommodation will then be the nearest point at which the examiner gets neutral motion. He notes the distance and converts it into diopters, allowing for the auxiliary lens if one were used.

The test is then made in exactly the same way for the other eye. The examiner now places his instrument and his eye directly in line with the patient's other eye and proceeds exactly as described above. It is desirable to use for the other eye a chart containing different letters and different arrangement of dots from the one used before. But this chart must be of the same general character as the other, namely, a fine-focussing chart.

An alternative method or one to be used as a check test is a method involving the use of the detailed "teaser" chart for locating the near point and amplitude, monocular at first. A "teaser" chart is placed about two inches in front of the examiner's nodal point, and is likewise a fine-focussing chart requiring critically fine accommodative adjustment. The examiner takes his position directly in line

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with the eye of the patient to be examined, the other eye being occluded. The examiner likewise begins his test from a distance outside the patient's near point, and asks the patient to read the letters or count the dots. As the patient focuses the "teaser" chart the examiner from his initial position gets an "against" movement. For the conjugate focus to the patient's retina is now about two inches in front of the examiner's nodal point.

The examiner now moves in towards the patient forcing the latter to continue his exact focussing of the "teaser" chart by one request or another for details of the chart, while he watches the reflex and shadow movements. As soon as the "teaser" chart comes within the patient's near point the against movement will become less marked and finally cease altogether, i.e., change to neutral. The examiner's eye is then at the near point of the patient. For even though the patient fixed the "teaser" chart he could not longer focus it, but was in focus for a plane beyond the chart. He was focussed for the nodal plane of the examiner's eye.

So much for the monocular near point and amplitude.

The binocular near point and amplitude are found in the following manner. The examiner places himself so that his eye and mirror and chart are located in the *median line* of the pa-

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tient, and the fine-focussing chart seen in the nodal plane of his own eye. The examiner places himself at some convenient distance outside the patient's near point, just as he did for monocular testing, and instructs the patient, whose both eyes are now uncovered and fixing the chart, to the examiner may use an auxiliary plus or read the letters or count the dots. Here, too, minus lens in order to bring the near point within a convenient range.

The examiner working rapidly from one eye to the other, a single flash in the horizontal meridian is all that is necessary, now makes his observations on the reflex and shadow movements. As the patient focuses the chart in the nodal plane of the examiner's eye, the examiner will get a neutral motion on first observation. He then moves in towards the patient along the patient's median line and continues his observations of reflex and shadow while the patient is made to continue fixing and focussing the chart by various requests for detail. The nearest point at which the neutral motion changes to with, is the binocular near point. Converting the distance into diopters gives the binocular amplitude, making allowance for an auxiliary lens if one were used.

For binocular testing too, the "teaser" chart may be used as an alternative method or check test. With the "teaser" chart of course, as

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explained previously in monocular testing, the initial movement is against, and the near point is the nearest point at which the against movement changes to neutral.

The binocular near point of accommodation is more easily obtained when the near point is at some distance from the patient. The alternate observation of the two eyes is then greatly facilitated. Therefore the use of a weak minus lens, say—1.00 or 2.00 is of advantage. With the "teaser" chart method this is especially helpful in cases of weak convergence, as the minus lenses at close range act like prisms base in. So that when the patient fixes the "teaser chart," the actual convergence used is a little less than is required for the distance. Thus when the examiner gets neutral motion, the end point of his examination, the patient both accommodates and converges for a plane beyond the chart fixed.

Dynamic Skiametry for Finding Relative Amplitude of Accommodation

A determination of the relative amplitude of accommodation will often throw light on a case of refraction that is of the utmost value. A test of the relative amplitude is pre-eminently a test of the strength of the inter-relation between accommodation and convergence, and of the extent of flexibility between these two func-

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tions. Such a test measures the free play of the accommodation against a fixed convergence. For such an important test, it is fortunate that there is an objective as well as a subjective method of determination. By both methods, the amount of relative accommodation may be found for any desired distance.

Relative accommodation, it may be well to recall, has two component parts, the positive portion and the negative portion, called respectively, positive relative accommodation and negative relative accommodation. The positive relative is the extent of the additional accommodation the eyes can exert for a fixed convergence over and above the amount started with at the time of fixing the target. The negative relative is the amount of accommodation the eyes can relax when urged to do so, for a fixed convergence, from the amount started with at the time of fixing the target.

For the proper determination of the positive and negative relative amplitude, it is important that the eyes be in focus for the target when initially fixing it. We can then measure the extent of increased activity or the extent of relaxation in the following manner.

The examiner places himself in the median line of the patient, using the fine focussing mirror chart described previously, so as to bring the fixation chart in the median line

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and in the plane of the examiner's nodal point. The patient with both eyes open and with his correcting lenses on is made to fixate the chart and to keep it in constant focus by the examiner's requests for finding missing letters, counting inner dots, and so on. Meanwhile the examiner watches the reflex and shadow, alternating rapidly from one eye to the other. A single flash along the horizontal meridian is all that is necessary. The distance he works at is the distance for which he wants to determine the amount of relative accommodation; and this may be any distance. He stays at that distance all through the test.

His initial observation will be neutrality of motion. To find the positive relative amplitude he now places binocularly minus lenses of increasing strength, starting with, say, O. U. —.50 D. and continuing with stronger lenses until the shadow changes from neutral to with. As the chart fixed required exact focusing the accommodation, when called upon, exerted itself to do so to the limit of its capacity of increasing its own activity without changing the convergence. This increased activity of the accommodation showed itself to the examiner by neutrality of motion, in spite of the minus lenses used. As soon as the accommodation could no longer be induced to further activity by the minus lenses, a with movement was obtained,

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showing insufficient accommodation for the distance. The strongest minus lenses that gave neutral measured the positive relative accommodation for that distance.

To determine the negative relative accommodation, the examiner proceeds in exactly the same manner as before with regards to fixation and observation. Except that now he places before the patient's eyes plus lenses of increasing strength, starting likewise, say, with O. U. +.50 D. The plus lenses force relaxation of the accommodation and the extent of the relaxation is noted by the strongest plus lenses that still gave neutral motion in the two eyes. As soon as an against movement is obtained the examiner knows that the eye is over-focussed because the accommodation did not relax sufficiently, and he stops. The strongest plus lenses that gave neutral motion, i. e., the lenses just before those giving against motion, represent the amount of negative relative accommodation for that distance.

A Unique Application of Dynamic Skiametry

The determination of the *exact* amplitude of accommodation of each eye separately, either by subjective or objective means, is really a very difficult matter. It is extremely difficult to make very accurate measurements of near point distances at close range where a differ-

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ence of an inch or less may make a difference in one or more diopters. Fortunately, exactness in determining the monocular amplitude, especially when this is high, is neither necessary nor of any special significance, except in one respect. And that is with reference to determining equality or inequality of the amplitude between the two eyes. This determination is important.

Inequality of amplitude of accommodation between the two eyes may be only apparent and due to an error in the ametropic correction. Such a finding will therefore act as a check on the distance correction. The examiner will seek to ascertain by a check test if this inequality can be removed by modifying the distance correction. If this can be done, good and well. But if after repeatedly checking the distance correction the inequality still persists, then the inequality is genuine. It may be due to some process, say, a sclerosis developing in the crystalline lens of one eye more rapidly than in the other, or to some local derangement affecting the ciliary muscle of one eye only.

The recognition of such inequality of accommodation is important from the standpoint of correction. It is, in general, desirable for comfortable vision at close range that both eyes exert equal quantities of accommodation. Where one eye is called upon to accommodate

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more than its mate, whether it can so accommodate unequally or not, strain is apt to result. In fact this is one of the causes of strain in cases of anisometropia. And inequality of accommodation is practically anisometropia at close range. In presbyopia such a finding will cause the examiner to consider giving unequal power additions to the two eyes for near work. In young people he may consider it wise to modify the distance correction so as to produce apparently equal amplitudes. But whatever steps he may take after finding the inequality is secondary to first finding it.

The inequality of accommodation may be either in the quantity of the accommodation or in the quality of the accommodation or in both. There is a subjective method for finding such inequality of accommodation, especially as to quantity, by rapidly comparing the vision of the two eyes when each focuses separately. The method is to dissociate the two eyes by means of a weak prism base down over one eye and base up over the other. A fine-focussing chart is then moved in towards the eyes while the patient fixes alternately the upper and lower chart. The examiner then learns from the patient whether or not the print blurs for both eyes at the same time. If there is inequality of amplitude the print will blur for one eye while still clear for the other. A similar test is con-

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ducted with cross-cylinders and cross lines.

This subjective test is mentioned and briefly described largely to show how inadequate it is as compared to the dynamic test. The subjective test leaves out of consideration the possibility and even the probability of slightly greater keenness of vision in one eye than in the other. It overlooks the prevalence of a dominant eye in the vast majority of individuals, which gives a stronger psychic, visual effect for that eye. These objections do not apply so much to the cross-cylinder cross lines method, which, however, is open to other objections. Furthermore all subjective tests for inequality are made during the absence of the necessary convergence innervation associated with the accommodation in the act of single binocular vision.

All these shortcomings are removed in the dynamic skiametry test for equality or inequality of accommodation. This test is therefore unique, being the only way of making such a determination accurately and doing it objectively at that.

The technique for making this test is as follows: The examiner places himself in the median line of the patient so that his own eye and the dynamic chart used are at an equal distance from each of the patient's eyes. The chart is seen in the plane of the examiner's

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nodal point by using the mirror chart described elsewhere. The chart used must be of the fine-focussing variety, containing very fine letters and very fine dots to be counted, so as to necessitate accurate focussing. This chart is similar to the one used for finding the near point and amplitude of accommodation by dynamic skiametry.

The patient with both eyes open is asked to count the dots or read the letters, or find missing letters, or find letters occurring twice or thrice or such other requests as will compel him to fully exert his accommodation all through the test. Meanwhile the examiner from his initial position, which is chosen at some distance beyond the patient's near point, watches the reflex and shadow movements, working rapidly from one eye to the other. A single flash in the horizontal plane is all that is necessary. As the examiner starts beyond the patient's near point, he will on first observation get neutral motion in each eye. He then moves in towards the patient, taking care to keep in the median line, while he continuously keeps shadowing the two eyes. As long as he gets neutrality of motion in the two eyes, they are both accommodating for the plane of the examiner's nodal point. It may be pointed out again that with the mirror chart, the print is seen in the nodal plane of the examiner's eye.

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If there is equality of accommodation in the two eyes then the neutral will change to a with movement at the same time in the two eyes. That is from a position of neutrality in both eyes the examiner on the next approach and the next flash will get a with movement in both eyes. But where there is inequality of accommodation the neutral will change to with in one eye before it will do so in the other. It will also be markedly with in that eye when it just turns from neutral to with in the other.

The test so far described is for finding equality or inequality in the quantity of accommodation in the two eyes. But a qualitative test of the accommodative mechanism in the two eyes can be similarly made by watching the sustaining power of the accommodation in the two eyes. If the examiner as he moves in towards the patient, especially so at close range, finds that the neutral movement in one eye changes to a with then again to a neutral on succeeding flashes, as compared to a steady neutrality in the other eye, he knows that he has a case of qualitative weakness of the accommodation in that eye. There is a lack of innervational or muscular force to sustain the actual contraction for as long a time in that eye as compared to the other. The wavering reflex and shadow in the eye with qualitatively poor accommo-

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dation is readily contrasted with the steady reflex and shadow in the other eye.

The dynamic skiametry test for equality or inequality of accommodation in the two eyes is made more easily with the "teaser" chart. This chart is set about two inches in front of the nodal point of the examiner's eye. The examiner uses the same technique as previously described for the mirror chart. But now as long as the patient focusses the chart, the examiner gets an against movement, as his nodal point is now behind the plane focussed. This against will naturally be his initial observation, as he starts from a point behind the patient's near point. He now moves in towards the patient and watches the reflex and shadow in the two eyes for any differences.

If there is equality of accommodation in the two eyes, the against movement will change to neutral, then to with at the same time in the two eyes. But where there is inequality of accommodation the changes will take place in one eye before they will in the other. There are three comparative observations possible, the against, neutral and with movements. Moreover, in the against and with movements inequality of accommodation is shown also by the difference in the speed and extent of shadow movements in the two eyes. There are also two stages, instead of one, for comparing the ob-

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servable reverses in the reflex and shadow, i. e., the change from against to neutral and from neutral to with. Qualitative inequality is readily observed during these transitions of movement from against to neutral to with by the unsteadiness and waywardness of the changes in one eye as compared with the other.

This test for quantitative and qualitative equality or inequality of accommodation in the two eyes is a delicate test and requires some experience for complete success. But it is not only a unique and sensitive test but one of genuine importance to the examiner. With a little patience and a good instrument the examiner will be well pleased, occasionally thrilled, with his success.

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CHAPTER V

SPECIAL TECHNIC

Anyone who can do static skiametry can do dynamic skiametry. The latter is doubtless a little more difficult than the former; but the elements of difficulty are sheerly matters of care and nicety in carrying out the details of the test, which are somewhat more exacting than those of the static. The steps in the two procedures are essentially alike, the reflex phenomena and their interpretations identical, and the apparatus employed the same. They differ only in detailed methods; and, so far as that is concerned, these details differ in either of the tests as practiced by different men.

Illumination

The same guiding rules which govern the performance of static retinoscopy apply equally to dynamic skiametry. This whole question is nowadays taken care of by the self-illuminating skiascope, of which there are several excellent makes on the market. This method of lighting

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is so superior in every respect to external sources of light that one is almost tempted to stop right there and to assert that no one should attempt dynamic skiametry with any other than a self-illuminated instrument. It affords a

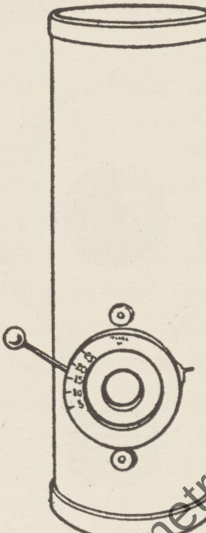

Fig. 16. A cylindrical metal chimney, with adjustable diaphragm, for use as a source of light in dynamic skiametry.

steady, uniform light, which can be quickly and easily regulated in size and intensity to meet the needs of the case, and it permits the operator constantly to direct the light along the desired axis of observation,—two considerations which sufficiently attest its working superiority.

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To those who for any reason prefer, or still continue to use, an external source of illumination, it will suffice to say that it should be at least a fifty candle power lamp, preferably incandescent, either enclosed in a cylindrical metal chimney with a diaphragm to emit the

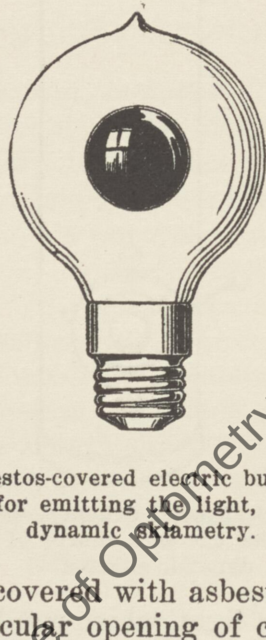

Fig. 17. An asbestos-covered electric bulb, with a circular window for emitting the light, for use in dynamic skiametry.

light, or else covered with asbestos all over except for a circular opening of convenient size. The former is probably the better plan, because the diaphragm can be varied in size to suit the distance at which the operator is working. Such sources of light should be mounted on some form of wall bracket, so that it can be moved

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forward or backward, up or down, with ease and rapidity.

It is a well-established axiom that proper illumination is the foundation of success in skiametry. And this axiom is particularly true in regard to dynamic skiametry, where the shadows are difficult enough to see and read, anyway, and where slight errors in reading them mean quite considerable errors in refractive equivalents, owing to the short focal distances at which one is working.

Let it be said again that by far the best and safest course is to employ a good up-to-date self-illuminating instrument.

Fixation

Fixation is at once one of the most important and one of the most troublesome factors in the technic of dynamic skiametry. Indeed, assuming the competency of the operator in general technic, it is at this point that the validity of the test most often falls down. It has already been pointed out that dynamic skiametry is an objective test involving some subjective elements. And fixation is one of these subjective elements. In the last resort it rests with the patient. Yet, unless it be properly and accurately performed, the accuracy of the finding is hopelessly vitiated, and the test might just as well never have been made.

We cannot, of course, coerce the patient, or

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compel him to fixate. Nor can we prevent him from fixating if he chooses to do it. But we can employ certain technical measures for the control of his fixation, and for our own checking purposes. The assumption is that the patient is there to be helped, and is in a willing frame of mind to cooperate with the operator in whatever is necessary to be done. In short, he will do what he is desired to do to the best of his understanding and ability. It rests with our technic to furnish him with the proper incentives and facilities to do what we require of him, and to furnish ourselves with the means of knowing whether or not he is succeeding in doing it.

Just what we wish him to do in the way of fixation depends upon which method of skiametry we are carrying out. The matter will therefore be discussed serially under these two heads.

Simple Fixation

If the method of the test is that of Cross' original procedure, i. e., to determine the point at which the patient's accommodation and convergence reach a comfortable inter-relation, then the fixation requirement is one of simple fixation, without regard to maintaining focus. In other words, the patient's accommodation is to be allowed a certain leeway of passivity, being permitted to relax under the influence of

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the added plus lens power up to the point where the comfortable accommodation-convergence relation is reached, and not stimulated or urged to relax beyond that point.

As previously explained, this is the more difficult of the two methods to control, and hence more likely to be inaccurate. Two considerations, however, help us here. First, we are dealing with an *instinctual* association of functions; and instinctive tendencies are exceedingly powerful things, operating with pretty constant dependability if given half a chance. Second, the purpose of the test is such that small deviations from exactness do not seriously vitiate the results. Even though we allow a margin of .50 D. one way or the other in our finding, we are still able to establish with sufficient accuracy the interlocking point between accommodation and convergence; and the margin of dioptric error can easily be rectified, in the final correction, by other means.

The best way, probably, to insure this flexible fixation-without-focussing on the part of the patient is by the use of fairly large letters, or perhaps no letters at all but a fixation picture or object, on the target. These can be seen, even under moderate "fogging," with sufficient clearness to satisfy the patient's curiosity urge, and thus furnish just enough mental stimulus to induce the normal surrender of accommodation,

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without imposing any compelling desire to visualize details.

At the start of the test, the patient both fixes and focusses the target. If the skiameter now shows a neutral reflex, we know that the eyes are fixing and focussing correctly. The patient is then instructed to keep a single image of the target, but not to be particular about its sharp-cut clearness; and we begin to put up plus lens power before the eye to be examined. If the patient's visual functions are normal, i. e., if the relation between his accommodation and his convergence is comfortable, the addition of plus lens power will not tempt him to make any change by surrendering any of his accommodation. He will maintain that comfortable relation, content to view the object, or the letters on the chart, in the somewhat blurred form given to them by the trial lens. In other words, he will make no attempt to "compensate" for the trial lens, preferring to maintain his comfortable accommodation-convergence unity even at the expense of a slightly blurred image. We have made it easy for him to follow this instinctive course, first by furnishing him letters or figures large enough to be easily deciphered under a blur, and second by instructing him not to bother about sharp definition of details.

If on the other hand, his accommodation, at the outset, be in excess of a comfortable ratio

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with his convergence, then he will readily surrender accommodation to the extent that the trial lens will replace it, continuing to do so, as more and more plus lens power is furnished him, down to the point where the comfortable

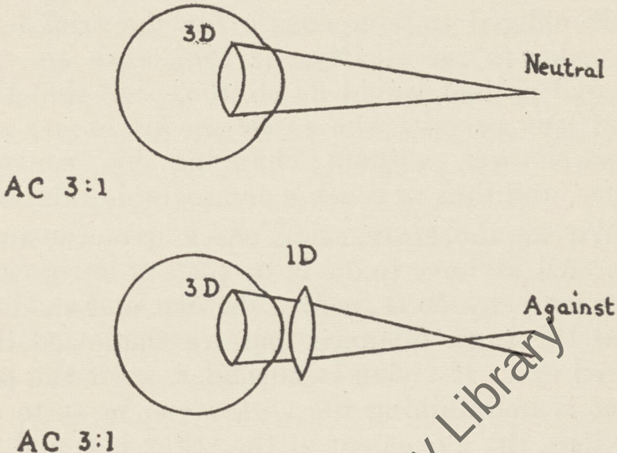

Fig. 18. Showing how the normal eye refuses to disturb its comfortable accommodation-convergence relation, under the simple fixation test, so that a plus 1D. lens reverses the emergent waves and the reflex. The hyperopic eye, being brought, by the aid of plus lens power, to this comfortable relation, thereafter behaves in the same way as the normal eye.

ratio is reached. After that, he will behave as the normal patient did, maintaining his comfortable relation in the face of any further added lens power.

The point is that under these conditions the

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patient is *not really making any effort to maintain a clear image.* He is merely hanging onto (if he be normal) or seeking (if he be abnormal) the comfortable relation between accommodation and convergence. In the case of excess accommodation it is not that the patient feels obliged to compensate for the trial lens in order to see clearly,—if that were so, the normal patient would do so, too,—but that the trial lens *permits him to let go his excess accommodation,* without changing his convergence, and thus to reach a comfortable relation.

We can, therefore, easily check up on the matter. All we have to do is to place a low-power plus lens, say. 50 D., before the eye, and shadow it at the same distance that we shadowed the naked eye. If vision is normal, i. e., if the patient is maintaining the *status quo* in spite of the lens, the movement of the reflex is found to be "against," due to the trial lens. If vision is not normal, i. e., if the patient's accommodation was originally in excess of convergence, the surrender of his accommodation compensates the trial lens and the reflex remains neutral.

Fixation and Focussing

In this case there is no question of allowing the functions of accommodation and convergence free play, to seek or maintain a comfortable inter-relation. Here we aim to compel the

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patient to keep both accommodation and convergence accurately adapted to the fixation distance, in spite of added plus lens power; in short, to compel him to compensate for the plus power of the trial lenses to the limit of his ability to do so.

Here, then, the two considerations which favored the simple fixation procedure are exactly reversed. First, we are attempting to overcome the instinctive tendency to comfortable accommodation-convergence relation by a deliberate effort to see clearly in detail. Second, the nature and purpose of the test are such that we cannot afford even small margins of error, since we are not dealing with comfortable relationships which adjust themselves, but with conjugate quantities.

To this end it is essential that the target of fixation shall embody some fine details, and that the patient be required at all times during the test to discern these details. It must be confessed that there is still much to be desired in the targets in general use or available at the present time. We shall have something to say on this point directly. For the present, it will suffice to say that the target should furnish the necessary stimulus to induce—virtually to compel—a surrender of accommodation in the face of plus lens power, to the limit of the patient's ability.

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As in the simple fixation procedure, the patient is asked at the outset to both fixate and focus the target; and the finding of a neutral reflex shows us that he is doing so. He is then instructed to maintain a steady, clear, detailed view of the target throughout the test. If we now begin to put up plus trial lenses before his eye, the patient, whether he be normal or abnormal, will make an effort to compensate for the lens, i. e., he will surrender his accommodation to the equivalent of the lens, so as to maintain the detailed view of the chart which he has been instructed to keep. This he will continue to do as long as he is able,—that is to say, to the limit of his range of negative relative accommodation.

The important point is that in this method of skiametry it is of the first importance that fixation and focussing be accurate and sustained; and therefore of equally primate importance that the ways and means of attaining them be adequate.

The Target

The nature and contents of the target depend, as intimated, upon the skiametric method to be employed. If it be the method of Cross, for determining the point of comfortable accommodation-convergence relation, then it had better consist of a few comparatively large letters, or not-too-detailed object, or a picture in rather

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bold outlines,—just enough to inspire the patient's desire (under instructions) to keep a fairly satisfying view, without inciting him to make strenuous effort to decipher details.

If the fixation-focussing method is to be used, for bringing into play the patient's negative relative accommodation, then the target should carry the most exacting and detailed characters that ingenuity can devise,—something which not only engages the sheerly visual at-

Fig. 19. Mixed-up letters to be picked out by the patient, and circle of dots to be counted, in the fixation-focussing test. (From Cross.)

tention, but calls into action some mental faculty. That which requires little or no focalizing, only a modicum of convergence, and practically no fusion, is valueless. As Fay McFadden well says, "To work thus loosely is to fail completely in the very fundamental principles of this form of dynamic skiametry."

The reading of words is altogether inadequate, because words are read by word-form, and not letter by letter. And the truth is that the mere deciphering of letters or figures is of

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itself hardly enough of a mental exercise to satisfy the demands of the test. Dots in odd groupings, inverted type, tiny drawings, and inverted figures to be added, are useful. Each operator will probably be able to devise for himself a set of charts which will meet the exacting needs of the case. Perhaps the best plan of all is to practice frequent changing of the charts, so that curiosity may be stimulated and memory outwitted.

One general rule can be laid down. Whatever the characters used, they should be of two or three different sizes, so as to correspond with the visual angle at different working distances. The proper-sized figures will thus become undecipherable at the slightest fogging, and compel the adjustment of the patient's accommodation in order to maintain a clear view of them.

With regard to the position of the target, that, again, will depend upon whether the operator employs the simultaneous-fixation-observation method of skiametry or makes his observation at one distance with the patient's fixation at another. In the former event, the best place for the target is probably attached to the front or top of the instrument, or to one side of it, or else on the operator's brow. In the latter case, it may be attached to an upright stanchio on a wheeled base, which can be moved readily back and forth to the required distance,

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or slung upon a cable, so that it can be slid to and fro. The cable can be graduated, as previously described, to serve also as a gauge for the working distance.

Whatever the device employed, the movable target must be so arranged as not to be too far out of the lateral plane of the patient's eye, so that the axis of observation may not be too far out of the patient's visual axis.

There is on the market at least one device, known as a dynamic fixator, for simplifying this

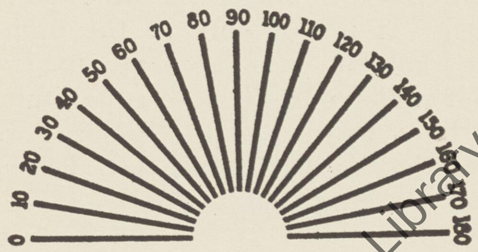

Fig. 20. Reverse side of chart shown in Fig. 19.

matter of fixation. It is an electrically illuminated target attached to a head-band which fits over the operator's head, and holds the patient's attention without wavering, permitting refraction very close to the line of vision. The illuminated portion, by means of an adaptor which fits any phorometer rod, can be detached from the head-band and used for all near-point tests.

One of the streak retinoscopes on the market

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carries its target on the front of the instrument, with a tiny but brilliant stage-light spotted on the chart,—a most compelling device for engaging the patient's attention. The charts can, of course, be slipped in and out of the slot in the target.

The Working Distance

The working distance is, strictly speaking, part and parcel of fixation. At all events, one is a function of the other, and it is of no avail to control the one unless the other be equally controlled. It is not only of the highest importance that we have accurate fixation, and know that we have it. It is of equal importance that we have fixation at a stipulated distance, and know that we have that, too. In short, accuracy of working distance is essential to the accuracy of the test. It will not do to take up an observation position somewhere about what we guess to be the distance at which we propose to work. Such loose methods in this respect are just as fatal to correct results as are loose methods in regard to the patient's fixation. The distance must be accurately measured, and "set off" by some mechanical means.

There seems to be an unfortunate lack of devices for insuring exact measurement of the working distance. Cross himself, if we remember correctly, was in the habit of using and recommending a graduate tape-line, or cable,

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stretched between the plane of the patient's eyes and a point behind the observer, and passing through a staple-ring attached to the skiascope, so that the instrument, as it moved back and forth, slid along the cable, which showed, at

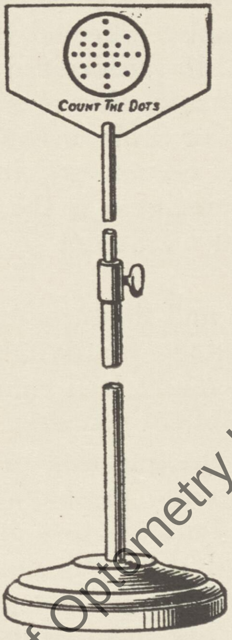

Fig. 21. Fixation stand. (From Cross.)

any given moment, the distance of the mirror from the patient's eye. This device has the additional advantage that where the operator practices observation and fixation at different distances, the target can also be slung on the

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cable, and moved back and forth to the graduated distances at which fixation is desired.

Probably a more accurate way would be to use fixators or chin-rests for both patient and operator, with a graduated sliding rod between them,—the patient's rest being stationary and the operator's on a wheeled base, so as to be readily movable to the desired distances. But, while more accurate, this is not so convenient as the tape-line, or cable, because it entails considerably more clumsiness in changing distances,—and clumsiness is the one thing above all others which ought not to characterize the dynamic test.

The devising and manufacture of a satisfactory distance gauge for dynamic skiametry is a matter which might well challenge the enterprise of some optical concern.

To revert to the question of the distance itself, apart from the mechanical means of attaining it, the dynamic test should always be made at several different distances, and not confined to what the patient gives as his customary working distance. Habit is a marvelous adapter. A man with a deformed leg may, by long practice, acquire the trick of walking so that nobody can detect that his leg is deformed. In like manner, a person with a defective accommodation-convergence-fusion function can, by long habit, acquire comfort and balance at

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his accustomed working point, which defies detection by skiametric tests. At an unaccustomed distance, the whole trouble instantly manifests itself. Probably the best order of procedure is first to make our test at some comparatively long distance, say at 40 inches; then come up to a very near point, say 13 inches. If these results substantially agree, making allowance for the normal differences, then a final test at "working distance" will permit us to prescribe the correction.

The Skiascope

No special form of instrument is required for dynamic skiascopy. The same instrument which is used for the static test can be used for the dynamic test, with this one proviso, that for the dynamic test the mirror must always be a plane mirror. The reason for this is obvious. The very essence of the dynamic test, by whichever method we apply it, is to induce surrender of accommodation to a certain given point, by means of plus-power trial lenses. The indication that this point has been reached lies in the fact that the moment it is passed an artificial myopia begins to be produced by the joint action of the patient's accommodation and the trial lens. It is evident, on the face of things, that such a procedure cannot very well be carried out with an instrument which itself produces the effect of an artificial myopia, by rendering

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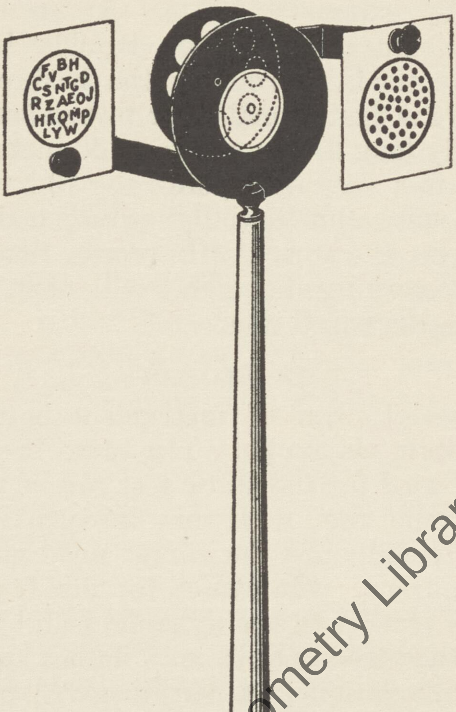

Fig. 22. Cross' double bracket skiascope. Note the two charts in different planes. In the final refining of the limit of neutralization the patient is required to shift his fixation from one to the other, instead of the observer being obliged to move nearer to and further from the patient.

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the light-waves convergent before they enter the eye.

With this proviso, there is no reason why the instrument to be used for dynamic skiametry should differ from the ordinary skiascope. This does not mean, of course, that any instrument is as good as any other for dynamic skiametry, provided it have a plane mirror. It means that whatever makes for a better instrument for the one purpose makes for a better instrument for the other purpose. And, inasmuch as the technic of the dynamic test is somewhat more exacting than that of the static, it is perhaps a little more important that for dynamic purposes we avail ourselves of the very best there is in the way of a retinoscope.

The prime factors of excellence in any skiascope are (a) a good, bright, uniform mirror-surface, (b) a well-made, not-too-large peep-hole, and (c) a convenient weight and form for steady handling. It has already been said, and may be repeated here, that a self-illuminating instrument is in all respects better than one which requires external illumination.

The Streak Skiascope

The principles of streak skiametry have already been discussed under the heading of The Optical Principles of Skiascopy, and its peculier advantages in dynamic skiametry pointed out.

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In using the streak skiascope, the operator observes the band reflex in the patient's eye, rather than the shadow. It is not necessary to study the movements of the diffuse shadow line,—a very difficult thing to do, especially in dynamic skiametry, where the reflexes are changing and the pupils are small. The lines of light with the streak are clear and their slightest movement easily seen. The intensity of the light can be adjusted to the degree of error.

In cases of astigmia, the straight line reflex is broken when the line of light is "off axis." When the line of light, as seen on the face, and the reflex line are in alignment, the exact axis of the astimia is found. The straight line of light thus acts as an axis finder by pointing to the degree marked on the trial frame. The eye is then shadowed by means of the line of light until the error is corrected in that meridian, and the streak rotated to right angles for shadowing the opposite meridian. The straight edge of the streak makes the shadowing of the meridian extremely easy, especially if the streak be narrowed down to a fine line, which points to the exact degree on the dial.

One of the streak skiascopes on the market is furnished with a mechanism by which all of these features,—the size and intensity of the illumination, and the rotation of the streak,—

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are readily and effectively controlled by the operator's finger, without stopping or interrupting the procedure.

Handling the Skiascope

Even in static skiametry, most writers and teachers advise against the practice of tilting the mirror itself in an attempt to produce movements of the shadow. On the other hand, many operators do practice this method of technic, apparently with success. The prime reasons against it are twofold: (a) it is likely to move the axis of the peep-hole so far out of alignment with the operator's eye that he is unable to see the reflex at all; (b) it requires an exceedingly steady and adept hand to insure the slight, firm movements desired. If the operator is sufficiently skilled and experienced to avoid these troubles, then it probably matters little what particular technic he chooses to employ. The average operator, however, will usually find that he can achieve his end much better by maintaining the fixed position of the skiascope against his brow and cheek, when he has once "found" the axis of vision through the peep-hole, and moving his head instead of the mirror to produce the reflex-movements. And this is particularly true in performing the dynamic test, because in this procedure one should make only the slightest of movements in order to produce and observe the reflex-movements to best advantage.

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With the streak skiascope, the direction in which the movements are to be made, in cases of astigmia, is readily shown by the straight edges of the light-band.

Operator's Correction

In general, it is unnecessary, in dynamic as in static skiametry, for the operator to wear his own refractive correction during the test, since it involves no fine conjugate relations between patient's and operator's retinae, as there is in ophthalmoscopy. He is, in reality, watching simply the movements of an aerial image, requiring only sufficient visual acuity to see them. It is, however, important that he be able to perceive the movements of the reflex, or of the light-band, readily and keenly; and if he is so myopic, or so astigmatic, that he cannot discern them properly with his naked eye, then he should wear his correction.

One of the streak skiascopes we have seen has a battery of plus lenses behind the peephole, which can be wheeled into position in order to provide for presbyopia on the part of the operator. An additional battery of minus lenses would similarly provide for troublesome degrees of myopia. Astigmatism is rarely so great as to interfere with satisfactory vision of the reflex; if it is, then the operator must have recourse to wearing his glasses.

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CHAPTER VI

THE TEST

We may now proceed to summarize the matter, and reduce it to terms of actual clinical practice, and to lay out explicit directions for the various steps in the procedure. The order of procedure will depend, of course, upon the purpose and method to be pursued, and these will be described separately.

The Simple Fixation Method

1. Seat the patient as for static skiametry, preferably with the head comfortably fixed in a head-rest. Seat yourself opposite, in such a position that your eyes are approximately in the same horizontal and lateral planes with those of the patient.

2. Put the target, containing the large-letter chart or not-too-detailed object, in place. Assuming that you are to make the mirror the point of fixation, attach it to the front or top of the skiascope, or to your brow.

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3. Measure off the required work distance between your own and the patient's eyes, by the means described under Special Technic, beginning at 40 inches.

4. Use your right eye to examine the patient's left, and *vice versa.*

5. Instruct the patient to fixate the target, and with the skiascope rapidly shadow the eye, moving slightly backward and forward until a neutral reflex is obtained, and carefully noting the distance. If the reflex moves "against" and cannot be neutralized by these slight adjustments back and forth, the eye is myopic with its far-point inside the 40-inch distance. Minus lenses must be mounted before it until the reflex is neutralized at the 40-inch point. This minus power is the measure of the excess myopia over 1 D. No further attention will here be given to a myopic case. It does not belong under dynamic skiametry.

6. Assuming that the eye is not thus shown to be myopic, mount a plus .50 D. lens before it, instructing the patient to maintain a single image of the target, but not to bother about too clear a view of the chart, and again shadow at the same distance. If the reflex has an "against" movement, the eye is emmetropic, or low myopic. If the reflex remains neutral, the eye is hyperopic, or, at all events, is using

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more accommodation than is comfortable at this distance, and the test must continue.

7. Continue to mount more and more plus lens power before the eye, shadowing carefully at each addition, until the reflex becomes just reversed to an "against" motion. Note the strength of the plus trial lens required to accomplish this.

8. Repeat the procedure at a distance of 13 inches, and note the strength of the plus lens required to just reverse the reflex. It will probably be a trifle more than the one required at 40 inches. If they are substantially in agreement, the finding may be regarded as indicating spherical hyperopia with no presbyopia.

9. Again repeat the procedure at the distance at which the patient says he ordinarily does his near work. The plus lens required to just reverse the reflex is the lens (spherical) he needs for correction at this point.

10. Go through exactly the same course with the other eye.

11. With the spherical correction thus obtained set in place before the patient's eyes, proceed now to shadow them, one at a time, at the patient's working distance, for astigmia, just as you would statically. For this test, however, the patient must steadily fix and focus the target.

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12. If the findings of Nos. 7 and 8 do not agree, but differ notably, a more extended exploration of the case is called for. Usually, when such differences are disclosed, the finding at 13 inches is considerably in excess of that at 40 inches, indicating deficient accommodation at the nearer point, which may be due to presbyopia, subnormal accommodation, defective tonicity, or other causes, which can only be determined by further tests.

13. Ascertain the patient's accommodative amplitude, by means of the procedure described at length in paragraph No. 14 of the Fixation-Focussing Method, below. If this shows a deficient amplitude, which accords with the excess finding of the previous test, the case is probably one of straight presbyopia. If the amplitude seems to be normal, and adequate, then it is probably a case of inefficient accommodation, calling for tonicity, fusion, and other tests.

14. If presbyopia is indicated, go back to the simple fixation test, and verify the plus lens needed at the patient's working distance to just reverse the reflex. This lens is his correction for this distance, and whatever it is in excess over distance correction should be added to the glasses for reading.

Illustrations

(1) At 40 inches it takes a plus 2 D. to reverse the reflex. At 13 inches it requires a plus

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2.25 D. The patient's customary working distance is 26 inches, and at this point it takes a plus 2 D. to reverse. Astigmatic tests show plus .50 D. axis 90, O. U. This patient is evidently a compound hyperope. Subtracting the .50 D. from the spherical finding for the lag, a correction of plus 1.50 D. spheres, plus .50 D. cyl. axis 90, O. U. will give him comfort and efficiency for his near work, and incidentally also for distance.

(2) At 40 inches it requires a plus 2 D. lens to reverse. At 13 inches it takes a plus 3.50 D. to reverse. It is evident that this patient is using 1.50 D. more accommodative effort at 13 inches than his showing at 40 inches would call for. Astigmatic tests are negative in result. Plainly this is a case of hyperopia with insufficiency of accommodation at close points. Perhaps a simple presbyope (if the patient's age is in accordance), perhaps some other condition. Such a case calls for further exploration of the entire accommodation-convergence-fusion function. Assuming, however, that it is a case of straight hyperopia and presbyopia, subtracting the usual .50 D., the correction will be plus 1.50 D. for distance with addition of another plus 1.50 D. for reading.

The Fixation-Focussing Method

Nos. 1 to 5, inclusive, are the same as in the simple fixation method, except that the target

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shall here contain the small, exacting characters as described for this method under Special Technic.

6. Mount a plus .50 D. lens before the patient's eye, instructing him to make an effort to maintain, throughout the test, a clear, detailed view of the target. In this case, whether the patient be emmetropic or hyperopic, the reflex will remain neutral, because he is obliged to equalize the trial lens by a surrender of his accommodation in order to keep a clear view of the target.

7. Continue to mount more and more plus lens power before the eye, shadowing carefully at each addition, until the reflex changes to "against." This indicates that the patient has reached the limit of his negative relative range. Note the strength of the plus lens needed to accomplish this.

8. Subtract .50 D. from the trial lens for lag. From the remainder, deduct 40% of 1 D., or .40 D., for the negative relative accommodation at 40 inches. What is left is the patient's excess accommodation, and the measure of his error at this point.

9. Repeat the process at 13 inches, making similar calculations, except that at this distance the negative relative accommodation must be figured as 45% of the normal accommodation for the distance, i. e., 45% of 3 D., or 1.35 D.

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If the excess accommodation at this point agrees substantially with the 40 inch finding, the case may be regarded as a straightforward one.

10. Again repeat the procedure and calculation at the patient's customary working distance. The excess accommodation which it reveals at this point is the proper working correction.

11. Go through the same course with the other eye.

12. With the spherical correction thus ascertained in place, proceed to shadow both eyes for astigmia, as described above.

13. If the excess accommodation as revealed by Nos. 8 and 9 are not in substantial agreement, further exploration is necessary, some of the steps of which still belong to dynamic skiametry, as follows:

14. Proceed to determine objectively the patient's accommodative amplitude. Remove all correction from the eyes. With a movable target, starting at a 40-inch distance, move the chart a little in advance of the mirror, and shadow the eye, instructing the patient to focus steadily, until a neutral reflex is obtained. Keep moving the target nearer and nearer to the eye, always a little in advance of the mirror, shadowing at each nearer point, until a point of nearness is reached beyond which neutralization can

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no longer be obtained, but an "against" movement appears. This is the patient's apparent near point, which, being translated into lens power by dividing into unity, represents the amplitude of accommodation.

If this amplitude be deficient, and the deficiency substantially accords with the insufficiency shown by the previous test, it is probably a case of presbyopia, natural or premature. If the amplitude is not deficient, i. e., if it is such that the patient ought to be able to exercise proper accommodation for 13 inches, then the case is one, not of insufficient, but of inefficient, accommodation, and still further investigation must be undertaken to determine the cause. These further investigations belong in other realms than dynamic skiametry, and consist chiefly in determining tonicity, duction, fusion, etc.

15. If deficient amplitude makes it probable that the case is one of presbyopia, abandon the fixation-focussing method at 13 inches, and resort to the simple fixation test for presbyopia, as described above.

ILLUSTRATIONS

(1) At 40 inches it takes a plus 2.90 D. lens to change the reflex. Subtracting .50 D. for lag leaves plus 2.40 D. as the actual reversing power. At 40 inches the normal accommodation is 1 D., of which 40%, or .40 D., is to be figured

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as negative relative accommodation. Subtracting .40 D. from the reversing power, 2.40 D., leaves 2 D. as the excess. At 13 inches it requires a plus 3.85 D. to reverse. Subtracting .50 D. for lag gives plus 3.35 D. as the true reversing power. At 13 inches the normal accommodation is 3 D., of which 45% is 1.35 D.,—the negative relative accommodation. Deducting 1.35 D. from 3.35 D. leaves 2 D., the excess accommodation. Evidently a simple case of 2 D. hyperopia.

(2) At 40 inches it takes a plus 2.90 D. lens to change the reflex. Subtracting .50 D. for lag, this becomes plus 2.40 D. By the same calculation as above this gives us an accommodative excess of 2 D. at this distance. At 13 inches we find that we are able to put up plus 3.50 D. lens power before the reflex shows any change from neutral. Testing the accommodative amplitude, we find it to be only 5 D. Abandoning the fixation-focussing method, and testing at 13 inches by the simple fixation procedure, we find that the patient accepts plus 3.50 D. before the reflex changes. His proper correction is plus 2 D. for distance, with plus 1.50 D. addition for close work. It is assumed that the astigmia tests were negative.

To recapitulate. The procedure for the fixation-focussing method is the same as for that of the simple fixation method, except for the

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use of fine, engaging targets, and the maintenance of a clear, detailed image, down to the point where the reversal lens is found. The excess accommodation, (which represents the hyperopic error), is then calculated as follows:

(a) Subtract .50 D. from the trial lens for "lag."

(b) at 40 inches deduct 40% of the normal accommodation, 1 D., or .40 D., for negative relative accommodation.

(c) At 13 inches deduct 45% of 3 D., the normal accommodation, or 1.35 D., for negative relative accommodation.

The remainder represents excess accommodation at the point in question.

If presbyopia discloses itself at either distance, abandon the fixation-focussing method, and proceed with the simple fixation.

Dynamic Fog-Skiametry

One of the most important applications of dynamic skiametry is to find the plens aid necessary for co-ordinating comfortably the functions of accommodation and convergence at the near working distance. And every examiner knows that such a comfortable adjustment for close work is more conducive to a patient's comfort than an exact correction of his distance ametropia. The technique for finding such lens aided by dynamic skiametry may be briefly summarized as follows:

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With the distance correction on, the patient is made to fixate a series of coarse letters or numbers or figures, so placed as to be in the nodal plane of the examiner's eye. As the test is binocular, it is also essential that the target be placed in the median plane of the patient and that the examiner's eye be placed in that same plane. The letters or figures on the chart should be sufficiently large so as to be easily visible under a blur of even 1 D. When these are about 5 mm. large, they subtend an angle of about 1 degree at a distance of about 30 cm. and not only can they be easily seen under a 1 D. blur, but the blur is hardly noticeable.

The examiner places himself in the right position at whatever distance from the patient that he wants to conduct the test and asks the patient to call aloud the letters or numbers, or name the geometric figures, while he makes his reflex and shadow observations on both eyes, working rapidly from one eye to the other. If there is neutrality of motion, he knows that the patient, is properly accommodating, that is, accommodating sufficiently for the distance of observation. But he does not know if such accommodation, while sufficient in amount or adequate for the distance, is produced under comfort or under strain. That is, the accommodative nerve impulse back of the muscular con-

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traction may be such as to be in harmonious relation with the converging impulse used at the same time, or it may be excessive.

To determine this point, the examiner now places plus lenses binocularly, starting with, say O. U. plus .50, and watches the reflex and shadow. If the movement is still neutral he knows the patient has relaxed a full half diopter of accommodation, while maintaining the same convergence. This would show him that the half diopter of accommodation relaxed was carried in *excess of the convergence,* and was therefore produced under a strain. For this reason it readily relaxed, though there was no visual need for such relaxation. The examiner then continues the same process, using stronger and stronger plus lenses binocularly, until he gets an "against" movement, when he stops. Suppose he gets an against movement when he reached O. U. plus 2.00, then O. U. plus 1.50 was the strongest lens giving neutrality, and this O. U. plus 1.50 is the lens necessary for bringing about a comfortable adjustment between the accommodation and convergence. The reason the accommodation did not relax beyond the O. U. plus 1.50 is that when the accommodation and convergence reached a comfortable adjustment with O. U. plus 1.50, they sort of interlocked. They reached a state of physiological equilibrium. And once in that

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state the eyes will not relax their accommodation and upset that equilibrium, when there is no visual urge for doing so. There was no visual urge since the target could be seen under a blur of a half diopter with the patient hardly being aware of the blur.

Of course, if the very first lens, say the O. U. plus .50 produced an "against" movement, then the examiner would at once stop. Apparently the eyes are perfectly balanced, and are interlocking in a comfortable adjustment of the accommodation and convergence. Therefore the eyes do not relax a full half diopter when there is no visual urge for doing so.

Where the examiner first finds a "with" movement then he knows that the accommodation is not sufficient in amount, that is in extent of muscular contraction for the distance of the examination. This irrespective of whether the nerve effort used is strained or not. He then starts with plus lenses, until he changes the "with" to "neutral," and continues with plus lenses until he changes the "neutral" to an "against." As in the preceding case, he takes the strongest plus lenses that produce neutrality of motion as the measure of the lens aid necessary to establish not only a sufficient or adequate *muscular* adjustment between the accommodation and convergence, but also a physiologically comfortable innerva-

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tional adjustment between the two functions.

It is, however, possible, and even probable, that in this procedure the accommodation *may* often relax a bit more than is physiologically necessary. That is, it may relax slightly below its comfortable locking point with the convergence, simply because it is in the course of a relaxing process. Like every other physiological activity, once started, it tends by its own inertia to continue a bit more than is necessary. Perhaps, natural laziness or the desire to relax whenever possible is also at the bottom of it, and may account for the accommodative lag, discussed elsewhere. The extent of this *excess* relaxation will of course depend upon the strength of the physiological interlocking between the accommodation and convergence.

To correct for this possible *excess* relaxation, Pascal has devised a dynamic procedure to act as a check test. He called this procedure dynamic fog-skiametry. The principle of the method is somewhat similar to the checking of the addition of a column of figures where, if one always adds from above downward, he checks it by adding from below upward, and vice versa.

In the ordinary procedure of the dynamic test as outlined in the first part of this chapter, the examiner goes from "with" or "neutral" to "neutral" and finally "against" mo-

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tion. In dynamic fog-skiametry he goes from "against" to "neutral" to "with." In the ordinary method of procedure, the patient usually goes from clear, focussed vision to slightly blurred, non-focussed vision. In dynamic fog-skiametry, he always goes from blurred, non-focussed vision to clear, focussed vision. In the ordinary method of dynamic skiametry, the accommodation is called up to relax *down* to its physiological locking point with the convergence, in which process it may relax too much and go *below*. In the dynamic fog-skiametry method, the accommodation is called upon to relax *up* to its physiological locking point and then to resume activity, in which process it will correct its previous *excess* relaxation.

The following illustration will make this clear. Suppose the examiner starts his *dynamic* test as outlined in the early part of this chapter. Suppose with proper binocular fixation and observation the examiner first gets neutral, with just the patient's distance correction on, then continues to get neutral with O. U. plus .50, O. U. plus 1.00, O. U. plus 1.50, then gets "against" with O. U. plus 2.00. As was discussed previously, this means the patient relaxes to the extent of 1.50 D. and no more. For check testing, the examiner now, preferably changing the fixation card to one of the same coarse type but with different letters or figures,

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places O. U. plus 2.50, which will produce still more marked "against" movement, and perhaps even force a bit more accommodative relaxation.

But now, still maintain the same fixation for the patient, the examiner proceeds, by reducing his plus lenses. He goes down to O. U. plus 2.00, getting "against" or possibly neutral, then to O. U. plus 1.50, getting neutral, then to O. U. plus 1.00, getting let us say, "with." He now stops. The lens aid required is O. U. plus 1.50, and the comfortable locking point is right there at the plus 1.50 addition.

For this reason, when the change was made from the plus 1.50 with neutral motion, to plus 1.00, an accommodative activity of .50 D. was called for, though mildly so, for exact focussing. The "with" movement with the plus 1.00 lenses shows the eyes have not made this accommodative effort, because accommodation and convergence interlocked at the plus 1.50 stage.

But suppose, as the plus lenses were reduced, O. U. plus 1.00 gave neutral, O. U. plus .50 gave "with," then the required lens aid is O. U. plus 1.00. For this reason, as the lenses were changed from O. U. plus 1.50 with neutral motion to O. U. plus 1.00, and still neutral motion, the eyes have exerted a full half diopter of accommodation in the process. The eyes did so, even though there was no strong visual urge

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for so doing, since the type could be seen well under the slight blur. We may say then that they did so exert some accommodation in order to get into a more harmonious relationship with the amount of convergence used. The .50 D. of relaxation found, where in the ordinary testing the examiner obtained neutrality with O. U. plus 1.00, and with O. U. plus 1.50, was an excess relaxation, and the O. U. plus 1.50 would therefore be too strong an addition.

In comparing the two techniques, several points of difference are to be noted, most of which were briefly mentioned before. One point of difference that was not mentioned before and which will now be clearly understood is this. In ordinary dynamic skiametry we stop at the first "against" movement and take as our finding the lens next weaker. In dynamic fog-skiametry we stop at the first "with" movement, and take for our finding the lens next stronger.

Dynamic Skiametry in Children

The possibility or rather the probability of latent hyperopia in children is, of course, always present. The problem of bringing this latent hyperopia to light has not yet been solved. Even hyperopia to light has not yet been solved.

Dynamic skiametry offers a fairly good method for ascertaining the presence and the amount of latent hyperopia. This, at least, as

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a first approximation. The method pursued for this purpose, is as follows. First find and measure the ametropia of each eye separately by ophthalmometry, static skiametry, and subjective tests. Place the correction thus found before the eyes and take the muscle balance by Maddox rod or any other suitable device. Where the tests indicate orthophoria or esophoria, and there is no reason to suspect this as a false finding, due to spasm of the internal recti, then the dynamic tests may at once be made in a manner to be described presently. But where the muscle tests, made more than once if necessary, point to exophoria, latent or manifest, then the dynamic tests must be made with some modification of technique. The presence of uncorrected exophoria will interfere with the dynamic test, and prevent the latent hyperopia from becoming manifest.

Assuming, in the first instance, that the muscle balance is true orthophoria or esophoria; the examiner places himself in the median plane of the patient and instructs the child to read the letters or figures or name the pictures on the fixation chart. This chart should contain type or figures of the coarse variety, i.e., large enough to be read even under a blur of a diopter or so. The fixation chart must also be placed so as to be seen in the nodal plane of the examiner's eye and be located along the

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median line of the patient. The examiner's eye behind the skiascope must be at an equal distance from each of the patient's eyes.

While the child with both eyes open fixes the chart, the examiner makes his reflex and shadow observations on both eyes, working rapidly from one eye to the other; a single flash in the horizontal meridian is all that is necessary. A neutral movement indicates perfect focussing for the distance of the examination. The examiner then places plus lenses of increasing strength before both eyes until he gets an against movement. He takes the lens just weaker as his finding for that distance. He now repeats the test at a closer range, using his previous findings as a starter and noting how much more plus, if any, it takes to get against movement at the closer range. He may then make a third trial by repeating the test at a still closer range and making similar observations. When no more plus is accepted before reversal at a closer point, than was accepted at the previous distance, then the examiner may consider the error as fully uncovered.

A good rule is to have at least 3 observation distances, say, at 30 inches, 15 inches, and a rather close distance, say, 8 or 9 inches. The younger the child the closer the last observation distance. At each of these distances the child will give up that excess of accommodation

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which he is carrying over and above the physiologically normal convergence for that distance. As the accommodation is allowed to relax but is not *forced* to relax he will not yield more than the excess accommodation. And this excess of accommodation as found at close range by the strongest plus lens giving neutral motion, most likely represents latent hyperopia. Of course, it may possibly represent a state of inefficiency of accommodation. But in an otherwise healthy youngster this is not likely. As far as utilizing the information found is concerned, it would not make much difference either. For the additional plus lens given, if it is given, would in either case be given for close range vision only.

The reason for making at least one set of observations at a very short distance is to arouse a strong accommodative activity due to nearness. Now, more than ever, the excess accommodation carried will become unduly burdensome and will readily yield to lens assistance. As Cross aptly phrased it, this would be like putting the last straw on the camel's back. The very close distance is also advantageous from another standpoint. Being a distance not ordinarily used by the patient it is free from the more or less tenacious habits of maladjustment between the accommodation and convergence acquired at other distances. Accordingly, at this distance, the natural tendency for a

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physiologically normal adjustment between the accommodation and convergence will be able to manifest itself without hindrance.

When exophoria is present or suspected, the dynamic, binocular test must be carried out a bit differently. The examiner and patient take the same position for observation and fixation as described before. But now, while the patient fixes with both eyes, the examiner shadows only one eye at a time. The other eye must carry during the entire examination of its mate the correcting base-in prism in order to relax the strain on convergence due to the exophoria. But even here the examiner must place his lenses before both eyes or else he will create a disturbing anisometropia.

Dynamic Skiametry with Fixation and Observation at Different Distances

The usual method of making a dynamic skiametry test is with fixation and observation in the same plane, whether we use straight dynamic skiametry or dynamic fog-skiametry as devised by Pascal. The method of dynamic skiametry with fixation and observation in different planes is seldom used. The inconvenience and bother of lugging around a fixation stand partly accounts for its disuse. But it has some good points to recommend it. For one thing it necessitates fewer lens changes than the other method. Fixation and observa-

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tion being entirely independent of each other, a greater range and variety of retinoscopic phenomena may be obtained. When the fixation stand is in front of the examiner nearly macular examination may be made, though when the stand is behind the examiner, marked obliquity is necessarily introduced.

The principle of the method stated in the "raw," so to say, is that the accommodation works in diopters to the full extent of the dioptric value of the fixation stand, practically irrespective of the ocular condition.

By noting the fixation distance, the observation distance and the strength of the lenses used, if any, the ametropia can be figured out by a simple calculation. The following examples will illustrate the method. Suppose the patient is made to fix the stand at 20 inches, and the examiner gets neutralization at 26 inches, with a plus 1.00 D. He then figures thus: Fixation at 20 inches aroused 2 diopters of accommodation, Therefore,

Fixation	+ 2.00 D
Lens	+ 1.00 D
Working allowance at 26″ as in static skiametry..........	— 1.50 D
Result	+ 1.50 D

The patient needs a + 1.50, he is 1.50 hyperopic.

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natural tendency to get to such physiological adjustment, which tendency had been thwarted by a refractive or muscular anomaly. The very presence of strain experienced in uncorrected errors points to the existence of a tendency towards harmonious co-ordination of all the ocular functions. The examiner using dynamic skiametry, especially the different-plane-fixation-observation method, must train himself to observe phenomena due to tendencies even before they have become fully manifest.

The example in myopia cited above when viewed in this light is not so impossible as it first reads. It is true, on first consideration, that a two diopter myope will not accommodate 1.50 D. when fixing a chart at 26 inches. The distance is beyond his far point, and any accommodation used would only make his vision worse. But at the same time the convergence of 1.50 meter angles probably arouses an associated *tendency* to accommodate 1.50 D. and it is up to the examiner to watch and correct according to the tendencies displayed.

Incidentally, this method of dynamic skiametry has been much used by state board examiners in framing questions for applicants. It lends itself to a variety of mild mental stunts.

Reconciling Static and Dynamic Findings

If one considers that, in general, static and dynamic skiametry are meant to be used for

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different purposes, then differences in the findings by the two methods are expected and readily explained. Static skiametry is primarily and almost wholly a method of finding the distance ametropia. Dynamic skiametry is primarily a method of finding near point corrections. Though, as mentioned elsewhere, dynamic retinoscopy has a number of applications, most of them centering around the near point findings.

However, in determining astigmia by static and dynamic skiametry there is often a difference in the results obtained by the two methods that examiners have found difficult to explain. Strictly speaking, structural astigmia must be the same whether the eye be adjusted for far or near vision. Where there is a difference in the astigmia, amount or axis or both, for far and near it is possibly due to sectional accommodation and is therefore false astigmia. Such astigmia should not be corrected with special cylinders for close work only. Rather, the condition causing sectional accommodation should be investigated and removed. Occasionally a torsion of the eyeball when adjusted for near vision will cause a difference in the position of the cylinder axes as found by static and dynamic skiametry. In such a case different cylinders may be required for far and near vision.

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In general, cases where the difference in the power and axis of the cylinder required for far and near vision is genuine, present a difficult problem to the examiner. But fortunately such cases are rare, very rare indeed. The reason refractionists so far found so many cases where the dynamic method showed a cylinder of different power or axis or both from that shown by the static method is because their static retinoscopy has been done under a marked obliquity of observation. Dynamic skiametry usually permitted an examination more nearly along the patient's visual axis, whereas static skiametry, as ordinarily practiced forced the examiner's line of observation to be markedly oblique to the patient's visual axis.

It is interesting to note that those cases in which the static skiametry examination was made practically along the visual axis the dynamic test gave the same results for cylinder strength and axis.

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CHAPTER VII

COLLATERAL TESTS

Both the necessity and the reasons for comparing and correlating the findings of dynamic skiametry with those of other tests, especially where the former do not work out simply and straightforwardly, has already been explained. It may not be out of place to add a few definite words as to the nature and significance of such collateral tests.

Subjective test-chart procedure and static skiametry should, of course, precede the dynamic test in every case. Nothing further need be said about these. The collateral tests here referred to are those which help to shed light upon abnormal functional relations between accommodative and fusional convergence, and between the positive and negative complements of relative accommodation. These are the elements whose disharmony upsets the flexible aspects of the nerve-muscle mechanism of vision; and their abnormalities, while they are disclosed by dynamic skiametry, can be investigated and determined only by means of other tests, here to be briefly enumerated.

Duction Tests

It is well known that when a prism is placed before one eye, the other eye fixing a definite test object at infinity, with the base of the

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prism in accurate position over one or other of the recti muscles, only that muscle which lies under the apex of the prism is stimulated to action. In this way, the independent, dissociated range of action of each rectus muscle can be accurately measured. It is best to make several such tests of each muscle, and average the results in each case. A comparison of the findings obtained for the two eyes will then serve to indicate which, if any, of the muscles is lacking in tone.

Duction tests of the oblique muscles are not quite so simple; but there are fairly accurate devices and methods in modern myology for carrying them out. The simplest and best known is that of the two Maddox graduated rods placed so as to give a vertical band or ribbon of light, the duction range of the obliques being measured by rotation of the band or rod to the point of breaking.

Binocular Tonicity Tests

Duction tests are, of course, in a sense, tonicity tests; but, as generally understood, tonicity tests are those which measure the range of the recti muscles in binocular action. There are various devices on the market for performing these tests, practically all of which are based upon the principle of a rotating prism, with the false image falling within the area of binocular fusion of the two eyes. The tonicity

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of the recti muscles is a highly important factor in the adjustment of accommodation-convergence relation, for the same reason that the hardening of the crystalline lens or a weakening of the ciliary disturbs it on the side of accommodation. Under conditions of defective tonicity the extrinsic muscles are exerting an innertion effort in excess of the convergence which they are achieving; and, it will be borne in mind, it is between accommodative and convergent *effort* that the functional relation obtains.

Version Tests

Version tests are tonicity tests of the conjugate range of the recti muscles, and are best carried out by means of some device constructed and operated on the principle of the perimeter. That is to say, with the patient's head fixed and immobile, the eye under examination (the other eye occluded) is required to follow a small object, preferably luminous, moved along the graduated meridian of a perimetric segment. Only the four cardinal meridians are to be explored, as the oblique muscles do not play a prime part in the movements, but only a corrective role.

Version tests serve as an exceedingly valuable check upon tonicity and duction tests, indicating whether defects disclosed by the tonicity tests represent mere functional inabilities of

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the muscle or muscles to coordinate with their fellows, or genuine muscular paralysis.

Accommodative Convergence

It has already been explained that a certain proportion of the convergence exerted at near points is stimulated by accommodation; and the remainder of the necessary convergence is negotiated by the fusion center. In order to determine how much of the total convergence at a given near point is being stimulated by the accommodation, it is necesary to employ a test which will (a) annul the fusion sense by destroying desire for a fused image, and (b) insure the full exercise of the accommodation for the distance in question. For this there are several devices and methods available, for which the reader is referred to works on muscles and muscle tests.

Two important facts are to be borne in mind in this connection. First, that the nearer the punctum proximum is approached, the greater is the accommodative effort as compared with the accommodative effect, so that the associated convergence produces an esophoria. Second, that in uncorrected hyperopia the accommodative convergence is usually greater than in emmetropia.

Fusion Convergence

There is no practical way of measuring the fusional complement of convergence. Having

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determined the amount of the accommodative complement for a given distance, the fusional complement may be assumed to be the remainder of the convergence which is mathematically normal for that distance. However, what is far greater importance is to ascertain what proportion of his fusional amplitude the patient is using in any given case; or, to state it the other way about, how much fusional range he still has in reserve. It is this fusional reserve, then, that is investigated. The test is relatively simple. It involves only some form of test object which will engage the full accommodation while at the same time affording a convenient lateral target (Sheard uses a vertical line of small letters), and graduated prism power which will displace the true and false images in a lateral direction. The amount of such prism which the eyes can overcome, maintaining both a single and a clear image of the line, indicates the fusion reserve. Comparing this with the fusional complement already calculated, we are able to determine whether the patient is using too large a proportion of his fusional element for comfort or for accommodation-convergence efficiency.

Undoubtedly fusion convergence is less stable, and therefore harder to maintain, than accommodative convergence, and excessive fusion convergence, therefore, is most affected by ocular fatigue.

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CHAPTER VIII

ILLUSTRATIVE CASES

Young man, aged 23. Static skiametry gave plus 1.50 D. in both eyes. Dynamic skiametry, by the simple fixation method at 40 inches: The reflex was just reversed in each eye by a plus 2.25 D. lens, which, with .50 D. deducted for lag, made the reversing power plus 1.75 D. By the fixation-focussing method: In each eye the reflex changed with a plus 2.50 D., which, after deducting the customary .50 D., gave plus 2 D. as the reversing power. Subtracting .40 D. for normal relative accommodation at this distance, we have 1.60 D. remaining as excess accommodation. At 13 inches by the simple fixation method, the reflex was changed by a plus 2.25 D., the same as at 40 inches, so that by the same calculation the reversing power was plus 1.75 D. By the fixation-focussing method at this distance, the reversing lens was plus 3.60 D. Subtracting .50 D. for lag gave plus 3.10 D. The normal negative relative accommodation at this point is 1.35 D. Deducting this from the 3.10 D. gives 1.75 D. as excess accommodation.

Convergence tests showed 4 d. esophoria without correction. Amplitude 8 D. The substantial agreement of all these tests with each other, and with the static findings, indicates a straightforward case of 1.75 D. hyperopia, with no accommodative deficiency. This correction was given, with satisfactory results.

Young lady, aged 30 years. This patient was a stenographer, and suffered severe discomfort from her work. Static skiametry gave plus 1 D. in both eyes. Dynamic skiametry at 40 inches, by the simple fixation test gave the following spherical findings for both eyes:

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Reversing lens ....plus	2.50 D.
Allowance for lag..................	.50
Reversing power....................	2.00

By the fixation-focussing method:

Reversing lens ....plus	3.00 D.
Allowance for lag..................	.50
Reversing power....................	2.50
Neg. Rel. Acc........................	.40
Excess accommodation..............	2.10

At 13 inches, by both methods, the excess accommodation proved to be a trifle more than at 40 inches. No astigmatism was discovered. Tonicity and convergence tests showed from 10 to 12 d. of esophoria. Amplitude 8 D. Apparently a case of ciliary spasm. The patient was given plus 1.50 D. lenses for both eyes, to be worn until the fogging first experienced had worn off. She came back, greatly improved, in about a month, at which time the strength of the glasses was increased to plus 2 D., both eyes. She is now free from all trouble.

Young man, aged 24 years. This patient was wearing minus .75 D. on both eyes, with which he said he saw all right, but complained of frontal headache, burning eyes, etc. Static skiametry seemed to justify the correction, giving close to minus .75 D. Dynamic skiametry by the simple fixation method, at 40 inches, however, gave the following:

Reversing lens........................plus	1.12 D.
Lag	.50
Reversing power....................	.62

By the fixation-focussing test at the same distance:

Reversing lens........................plus	1.50 D.
Lag	.50
Reversing power....................	1.00
Neg. Rel. Acc........................	.40
Excess accom........................	.60

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Tonicity tests showed slight esophoria; convergence tests 4 to 5 d. esophoria, without lenses.

This was evidently a case of spasmodic hyperopia, simulating myopia. The minus glasses were replaced with plus .62 D. for both eyes, with which, fortunately, the patient was immediately able to read 20/20. This correction has given complete satisfaction.

(From Sheard): A young university student, aged 21 years, using his eyes quite closely, complained of no other symptoms than eye fatigue. Static skiametry showed nothing. Subjective tests were likewise neutral. Dynamic skiametry, by the fixation-focussing method, as practised by Sheard, gave plus 1.25 D. as the neutrali showed a decidedly "with" motion, which required a plus 1.25 D. to neutralize the reflex, both eyes. Duction tests were normal. Amplitude 8 D. for each eye. But accommodative convergence tests showed 6 d. of esophoria. This patient was given plus 1 D., both eyes, for reading, wholly in the interest of correlating accommodation and convergence at reading point.

The instructive feature of this case is that if the examiner had been content with the static and distance subjective tests, and the subjective method of determining the amplitude, he would have reached the conclusion that the patient needed no glasses. It was the dynamic test, in conjunction with the accommodative convergence test, that revealed the true state of the case.

Young woman, bookkeeper, aged 30. Complains of headache and other asthenopic symptoms toward the end of the day's work. Wearing the following correction:

O. D. plus 1 D. S. with plus .75 D. ax. 90°
O. S. plus 1 D. S. with plus .50 D. ax. 90°

Static skiametry gave the same results as embodied in patient's present glasses. Dynamic skiametry, at 20 inches, by the simple fixation method, gave spherical findings as under:

Reversing lens......................	plus 2.00 D.
Deduction for lag....................	.50
Reversing power.....................	1.50

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By the fixation-focussing method at 20 inches:

Reversing lens......................plus	3.00 D.
Deduction for lag....................	.50
Reversing power.....................	2.50
Neg. Rel. Accom....................	.80
Excess accom.........................	1.70

Dynamic astigmatic test showed:
O. D. plus .75 D. ax. 75°
O. S. plus .50 D. ax. 105°

Prescription was given as follows:
O. D. plus 1.50 D. S. with plus .75 ax. 75°
O. S. plus 1.50 D. S. with plus .50 ax. 105°

With this correction the patient experienced a little spherical "fog" for a week or two, after which it proved very satisfactory. Note the change in the axes of the cylinders.

Business man, aged 51 years. Never been able to read satisfactorily. Wearing a pair of plus 1 D. which he "picked up" in a jewelry store a few years ago.

Static test gave both eyes as plus 1.25 D. Dynamic test at 40 inches, by simple fixation method, gave:

Reversing lens......................plus	2.25 D.
Deduction for lag....................	.50
Reversing power.....................	1.75

By the fixation-focussing method:

Reversing lens......................plus	2.66 D.
Deduction for lag....................	.50
Reversing power.....................	2.16
Neg. Rel. Accom....................	.40
Excess accom.........................	1.76

At 13 inches, by the simple fixation method, the patient accepted plus 3.75 D. before the reflex changed. Deducting the .50 D. allowance for lag, this indicated 3.25 D. accommodative effort surrendered in exchange for lens power. Subtracting the 1.75 D. already manifested at 40 inches,

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it was evident that the patient had 1.50 D. presbyopia. Examination at 13 inches by the fixation-focussing method was contraindicated. Glasses were prescribed as follows:

O. U. plus 1.75 D. Reading addition plus 1.50 D.

Housewife, 32 years of age. Had recently undergone a severe surgical operation, from which she has even yet hardly recovered. Finds considerable trouble in reading. Has periodical squint.

Static skiametry reveals no refractive error. Dynamic skiametry, at 40 inches, gives the following:

O. D.	Reversing lens	plus 1.00 D.
	Lag allowance	.50
	Reversing power	.50
O. S.	Reversing lens	plus 1.25 D.
	Lag allowance	.50
	Reversing power	.75

By the fixation-focussing method:

O. D.	Reversing lens	plus 1.50 D.
	Lag allowance	.50
	Reversing power	1.00
	Neg. Rel. Accom	.40
	Excess accom	.60
O. S.	Reversing lens	plus 1.75 D.
	Lag allowance	.50
	Reversing power	1.25
	Neg. Rel. Accom	.40
	Excess accom	.85

At 13 inches, by the simple fixation method:

O. D.	Reversing lens	plus 2.50 D.
	Lag allowance	.50
	Reversing power	2.00

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O. S. Reversing lens	plus 2.75 D.	
Lag allowance	.50	
Reversing power	2.25	

Refractive tests were broken off at this point. Duction tests showed marked and irregular deficiencies. Accommodative convergence tests revealed varying exophoria. The amplitude, measured by the dynamic method, was O. D. 4 D., O. S. 3.5 D.

In view of the physical history, this was probably an instance of muscular weakness due to ill health and strain. The patient was advised to give the eyes complete rest for several months, and return for another examination. Six months later, dynamic skiametry showed the error to be a simple case of .50 D. hyperopia in both eyes, with normal duction and convergence findings.

Young lady, 26 years of age. Library assistant. Wearing glasses, plus 1 D. S. both eyes. Complained of eye strain.

Static skiametry gave:

O. D. plus 1.50 D. C. ax. 90°

O. S. plus 1.50 D. S., plus 1.50 D. C. ax. 105°

Dynamic skiametry, by the simple fixation method, at 40 inches, gave the following:

O. D. Reversing lens	plus 1.00 D.
Lag allowance	.50
Reversing power	.50
O. S. Reversing lens	plus 3.00 D.
Lag allowance	.50
Reversing power	2.50

By the fixation-focussing method:

O. D. Reversing lens	plus 1.50 D.
Lag allowance	.50
Reversing power	1.00
Neg. Rel. Accom	.40
Excess accom	.60

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O. S. Reversing lens..................plus 3.50
Lag allowance.................. .50
———
Reversing power................. 3.00
Neg. rel. accom................. .40
———
Excess accom................... 2.60

At 13 inches, by the simple fixation method, the results were just .12 D. more than 40 inches for each eye. By the fixation-focussing test the findings were as follows:

O. S. Reversing lens..................plus 2.33 D.
Lag allowance................. .50
———
Reversing power............... 1.83
Neg. rel. accom................. 1.33
———
Excess accom................... .50

O. D. Reversing lens.......................plus 4.33
Lag allowance................. .50
———
Reversing power............... 3.83
Neg. rel. accom............... 1.33
———
Excess accom................... 2.50

Dynamic astigmia tests gave the following:
O. D. plus 2 D. axis 80°
O. S. plus 2 D. axis 100°

Tonicity tests showed 3 d. esophoria; accommodative convergence tests gave 7 d. esophoria.

Glasses were prescribed for this patient as follows:
O. D. plus .50 D. S. plus 2 D. C. axis 80
O. S. plus 2.50 D. S. plus 2 D. C. axis 100
which at first gave considerable blurring, but within a month or so were found entirely satisfactory.

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